SOLUBILITY OF CARBON DIOXIDE (CO_2) FROM NATURAL GAS USING VARIOUS TYPES OF AMINE-BASED SOLVENTS

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CHEMICAL ENGINEERING
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Solubility of Carbon Dioxide (CO_2) From Natural Gas Using Various Types of Amine – Based Compounds

By

Emy Marlina Binti Samsudin

DISSERTATION

Submitted in Partial Fulfillment
of the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

JUNE 2009

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CERTIFICATION OF APPROVAL

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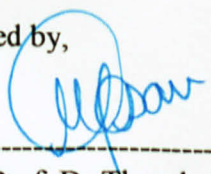

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JUNE 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(EMY MARLINA BINTI SAMSUDIN)

UNIVERSITY TECHNOLOGY PETRONAS

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"When you want what you've never had, you have to do what you've never done... ...."

ABSTRACT

This final report emphasized on the project title *"Selectivity of Carbon Dioxide (CO_2) Removal in Natural Gas Using Various Type of Amine-Based Compound.* It consist multiple sections ranging from project background, literature review, methodology, results and discussion and conclusion.

The objective of this project is to evaluate the solubility of carbon dioxide in various amine compounds by performing laboratory experiments (batch process), using various amine mixtures and ratios, manipulated system temperature and carbon dioxide partial pressure. These amine-based compounds include secondary and tertiary amine mixtures, where methyethanolamine (MDEA) is supported by a promoter or activator.

The equipment setup for the laboratory analysis involves High Pressure Gas Solubility Cell (MODEL BP 22). This equipment has been designed for measurements of gas solubility in liquid at high pressure and temperature. The unit is capable of determining the solubility of gases in various liquid, effect of temperature and pressure on the component solubility, formation of methane hydrate and other complexes under high pressure and reduction of solubility after repeated solution stripping cycle. Also included in this report are the experiment layouts and the calculations involved in preparing the desired amine solutions.

In order to correlate the project objectives with the laboratory outcome, literature search is conducted aiming at journals, articles, literature reviews, chemical engineering books and also personal interviews. Based on the literature reviews, journals and related articles, important findings have been studied and extracted from successful researchers such as Mohamed Idali et al.(2007)., Sanjay Bishnoi et al. (2002)., Hua-Bing Liu et al.(1999)., Chakravarty et al.(1985) and many more.

It is proven statistically by experimental analysis that mixtures of blended amines are able to yield positive result in carbon dioxide absorption from natural gas. In addition,

certain ratios of blended amines are able to increase the selectivity of carbon dioxide gas removal, and at the same time offers low regeneration cost, less corrosive and lower circulation rate. However, carbon dioxide partial pressure and temperature of the system plays a major role in promoting the right environment for the carbon dioxide selectivity. Graphical representations of the experimental result are displayed in this report together with its explanation, supported by work done by successful researchers mentioned above. The results are then finally summarized in the conclusion section. Recommendations will be made in order to achieve better performances in laboratory work and industrial practices. Targeting in improving the real-world industrial processes, it is hope that a profitable outcome will be obtained at the end of this project.

CHAPTER 1
INTRODUCTION

1.1 Background of Study

1.1.1 Natural Gas

Natural gas is colorless, shapeless, and odorless in its pure form. It is a gaseous fossil fuel consisting primarily of methane but including significant quantities of ethane, propane and butane The composition of natural gas can vary widely, but below is a chart outlining the typical makeup of natural gas before it is refined. (Refer ***Table 1.1***).

Table 1.1: Typical Composition of Natural Gas

Composition	Symbol	Amount (in Percentage)
Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	0-20%
Butane	C_4H_{10}	0-20%
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen Sulfide	H_2S	0-5%
Rare Gases	A, He, Ne, Xe	trace

Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, the natural gas is 'wet'. It is found in oil fields (associated) either dissolved or isolated in natural gas fields (none associated), and in coal beds (as coal bed methane).

Natural gas can be measured in a number of different ways. As a gas, it can be measured by the volume it takes up at normal temperatures and pressures, commonly expressed in cubic feet. Production and distribution companies commonly measure natural gas in thousands of cubic feet (Mcf), millions of cubic feet (MMcf), billions of cubic feet (Bcf), or trillions of cubic feet (Tcf). While measuring by volume is useful, natural gas can also be measured as a source of energy. Like other forms of energy, natural gas is commonly measured and expressed in British thermal units (Btu). One Btu is the amount of natural gas that will produce enough energy to heat one pound of water by one degree at normal pressure.

1.1.2 Formation of Natural Gas

There are many different theories as to the origins of fossil fuels. The most widely accepted theory says that fossil fuels are formed when organic matter (such as the remains of a plant or animal) is compressed under the earth, at very high pressure for a very long time. This is referred to as thermogenic methane. Similar to the formation of oil, thermogenic methane is formed from organic particles that are covered in mud and other sediment. Over time, more and more sediment and mud and other debris are piled on top of the organic matter. This sediment and debris puts a great deal of pressure on the organic matter, which compresses it. This compression, combined with high temperatures found deep underneath the earth, break down the carbon bonds in the organic matter. The deeper under the earth's crust, the higher the temperature. At low temperatures (shallower deposits), more oil is produced relative to natural gas. At higher temperatures, however, more natural gas is created, as opposed to oil. That is why natural gas is usually associated with oil in deposits that are 1 to 2 miles below the earth's crust. Deeper deposits, very far underground, usually contain primarily natural gas, and in many cases, pure methane.

Natural gas can also be formed through the transformation of organic matter by tiny microorganisms. This type of methane is referred to as biogenic methane.

Methanogens, tiny methane producing microorganisms, chemically break down organic matter to produce methane. These microorganisms are commonly found in areas near the surface of the earth that are void of oxygen. These microorganisms also live in the intestines of most animals, including humans. Formation of methane in this manner usually takes place close to the surface of the earth, and the methane produced is usually lost into the atmosphere. In certain circumstances, however, this methane can be trapped underground, recoverable as natural gas. An example of biogenic methane is landfill gas. Waste-containing landfills produce a relatively large amount of natural gas, from the decomposition of the waste materials that they contain. New technologies allow this gas to be harvested and added to the supply of natural gas.

A third way in which methane (and natural gas) is believed to be formed is through abiogenic processes. Extremely deep under the earth's crust, there exist hydrogen-rich gases and carbon molecules. As these gases gradually rise towards the surface of the earth, they may interact with minerals that also exist underground, in the absence of oxygen. This interaction may result in a reaction, forming elements and compounds that are found in the atmosphere (including nitrogen, oxygen, carbon dioxide, argon, and water). If these gases are under very high pressure as they move towards the surface of the earth, they are likely to form methane deposits, similar to thermogenic methane.

1.1.3 Natural Gas Processing

Natural Gas is a vital component of the world's supply of energy. It is one of the cleanest, safest, and most useful of all energy sources. Unlike other fossil fuels, natural gas is clean burning and emits lower levels of potentially harmful byproducts into the air.

Before natural gas can be used as a fuel, it must undergo extensive processing to remove almost all materials other than methane. The by-products of that processing include ethane, propane, butanes, pentanes and higher molecular

weight hydrocarbons, elemental sulfur, and sometimes helium and nitrogen. Various unit processes are used to convert raw natural gas into sales gas pipelined to the end user markets. The raw natural gas must be purified to meet the quality standards specified by the major pipeline transmission and distribution companies. Those quality standards vary from pipeline to pipeline and are usually a function of a pipeline system's design and the markets that it serves.

The major units and its respective processes are summarized as below:

1. Acid Gas Removal Unit: Amine Treating, Benfield Process, etc.
2. Sulfur Unit: Claus Process
3. Tail Gas Treating Unit (TGTU): Scot Process, ClausSpol Process, etc.
4. Dehydration Unit: Glycol and Pressure Adsorption Process Units
5. Mercury Removal Units: Mol Sieve and Activated Carbon as adsorbent
6. Nitrogen Rejection: Cryogenic Process
7. Natural Gas Liquids (NGL) Units
8. Fractionation Train Units: Deethanizer, Depropanizer, Debutanizer
9. Sweetening Unit: Merox Process, Sulfrex Process, etc.

Processing of the raw natural gas yields these byproducts:

- Natural gas condensate
- Sulfur
- Ethane
- Natural gas liquids (NGL): propane, butanes and C_5+ (which is the commonly used term for pentanes plus higher molecular weight hydrocarbons)

1.1.4 Usage of Natural Gas

Natural gas ranks number three in energy consumption, after petroleum, which provides almost 39 percent of total energy demand, and coal, which provides 22.6 percent. (Adapted from The Need Project, United States 2008).

Industry is the biggest consumer of natural gas, using it mainly as heat source to manufacture goods. Industry also uses natural gas an ingredient in fertilizer, photographic film, ink, glue, paint, plastic, laundry detergent, and insect repellents. Synthetic rubber and man-made fibers like nylon also could not be made without the chemicals derived from natural gas.

Natural gas is also used to make electricity. It is the third largest producer of electricity after coal and uranium. Many people in the in the energy industry believe natural gas will play a bigger role in electricity production as the demand for electricity increases in the future.

Natural gas power plants are cleaner than coal plants and can be brought on-line very quickly. Natural gas plants produce electricity more efficiently than new coal plants and produce it with fewer emissions. To a lesser degree, natural gas is sometimes used as a transportation fuel.

1.2 Problem Statement

Carbon Dioxide (CO_2) is one of the contaminants present in raw natural gas which need to be removed before processing the natural gas further in a natural gas processing plant. Combination of CO_2 with water creates carbonic acid which leads to corrosion. Besides that, presence of CO_2 in natural gas reduces British Thermal Unit (BTU) value of gas and in concentration of more than 2% or 3%, the gas is unmarketable. There are also fixed quality standards specified by the major pipeline transmission and distribution companies that need to be aligned with the quality of the natural gas processing products.

1.3 Objective

1. To study on the solubility of CO_2 using amine-based mixtures operated at different temperature, pressure and concentrations:

    a. Methyl Diethanolamine (MDEA) + Water (H_2O)
    b. Methyl Diethanolamine (MDEA) + Diethanolamine (DEA) + Water (H_2O)
    c. Methyl Diethanolamine (MDEA) + Piperazine (Pz) + Water (H_2O)
    d. Methyl Diethanolamine (MDEA) + Diethanolamine (DEA) + Piperazine (Pz) + Water (H_2O)

1.4 Scope of Study

To fulfill the objectives, many literature reviews, journals, articles from renowned researcher relating to the objective of the project are to be collected and studied. It is very important that their scope of research is well understood in order to increase knowledge and understanding plus maximizing ideas during the duration of the project research.

Laboratory work plays a major role to analyze the trend behavior of CO_2 removal from natural gases. The experiments involve manipulating the temperature of the system, partial pressure of carbon dioxide (CO_2), total concentration of the solvents used, and type of amine-based compounds. The feed ratios and flow rates are kept constant since it is a batch processes. With each of the manipulation variables, the potential behavior of CO_2 removal in natural gas from all the experiments data will be used for further discussion. The regeneration methods of amine processes will be studied and ideas will be contributed on the most sufficient and economical methods.

CHAPTER 2

LITERATURE REVIEW

2.1 The Importance of Natural Gas Sweetening Process

Acid gas is a gas containing acidic components such as carbon dioxide (CO_2), hydrogen sulphide (H_2S), carbonyl sulphide (COS) and carbon sulphide (CS_2) that can form acidic solutions when mixed with water. Acid gas mainly contains of CO_2 and H_2S gases. Both gases can cause corrosion which forms carbonic acid with the presence of water. The CO_2 concentration must be removed to less than 2%. The presence of CO_2 must also be removed prior to low temperature processing for NGL recovery. Any cryogenic gas separation process requires the upstream removal of H_2S, CO_2 and COS as typical sour gas impurities to meet the specification for clean products and prevent their plugging of the process equipment. Furthermore, acid gas affects the British Thermal Unit (BTU) of the gas by lowering its BTU value. A lower BTU value indicates lower energy content, hence providing a lower quality of fuel.

2.2 Natural Gas Sweetening Process

Varying from a few years back to the recent technology, there have been many methods for the removal of acid gases from natural gas in the industry. The processes include:

- Chemical Absorption - Amine mixtures (operated at ambient temperature)
  - Hot potassium carbonate solution (100-110°C)
- Physical Absorption - IFPEXOL, Selexol, Rectisol, Purisol, Sulfinol Process
- Adsorption - Activated alumina, silica gel, activated carbon, molecular sieve
- Others (e.g., membranes)

The characteristics of the process type very much depend on the concentration of the acid gases and the required specifications of output.

As for chemical absorption, the challenge faced is from keeping the solvent clean and operating within the process constraints of the system. Membrane systems also have been used for CO_2 removal. One challenge for membrane systems is reaching the low allowable CO_2 levels required by the pipeline system. Using adsorbent (molecular sieve system) for CO_2 removal can, for certain applications, allow for CO_2 removal without the operational challenges of amine based systems or the process limitations faced by the membrane systems.

2.3 Amines Sweetening Units

The technology of using alkanolamines for removal of hydrogen sulfide and carbon dioxide from natural gases has been used for decades. Since the 1960's and 70's several amines have come into general use, however, limited information has been reported in the literature concerning the amine best suited to a particular service. Many amine units which are operating very inefficiently could be optimized by simply changing amines. Some of the factors to be considered in the selection of the proper amine for design or existing plant evaluation include:

- Amine circulation rate at different amine concentration/ acid gas loading
- Reboiler/ condenser size and duty at different amine circulation rate or lower heat of reaction with H_2S and CO_2
- Optimizing H_2S and CO_2 absorption by use of amine mixtures
- Resistant to Corrosion/ Amine Degradation
- Relationship of efficiency with alternate flow schemes of process

According to Astarita, et al. (1983) 50 to 70% of the initial investment for an amine sweetening units is directly associated with the magnitude of the solvent circulation rate, and another 10 to 20% of the initial investment is dependent on the regeneration energy requirement. In addition, about 70% of operating costs, excluding labor, result from regeneration. Since selection of proper amine can greatly reduce both the regeneration energy requirement and solution circulation rate, choice of amine or combination of

amines best suited to the conditions can have a dramatic impact on the overall costs associated with a sweetening unit.

2.3.1 General Considerations for Selecting Amines

The general criteria for amine selection in sweetening plants have changed over the years. Until 1970's monoethanolamine (MEA) was the amine first considered for any sweetening application. Then in the 1970's, as mentioned in papers by Beck (1975) and Butwell and Perry (1975), switching from MEA to diethanolamine (DEA) yielded favorable results. In the past ten years, MDEA, DGA and mixed amines have steadily gained popularity.

As different operating conditions are tested and proven with a particular amine, they become accepted on an industry-wide basis. Thus each amine has a currently "accepted" range of process conditions and parameters associated with it which is further elaborated below.

- **Monoethanolamine (MEA)**

MEA is generally used as a 10 to 20 weight% solution in water. Due to corrosion problems, the acid gas loading is usually limited to 0.3 to 0.35 moles acid gas per mole of amine for carbon steel equipment. Loadings as high as 0.7 to 0.9 mole/mole have been used in stainless steel equipment with no corrosion problem. Although MEA itself is not considered to be particularly corrosive, its degradation products are extremely corrosive. Degradation or deactivation of MEA lowers the effective amine concentration but fortunately a reclaimer can recover most of the deactivated amine. According to Bryan Research and Engineering, Inc. since the heat of reaction for MEA is about 825 BTU/lb CO_2, a feed gas containing high concentrations of CO_2 will cause either extremely high reboiler duty, or poor acid gas stripping.

- **Dethanolamine (DEA)**

DEA is most commonly used in the 25 to 35 weight% range. The total acid loading for DEA is also limited to 0.3 to 0.35 mole/mole for carbon steel equipment. DEA can safely be loaded to equilibrium (~1 mole/mole) when using stainless steel equipment or when using inhibitors as in the SNPA process (Kohl and Reisenfeld, 1979). Since DEA is a secondary alkanolamine, it has reduced affinity for H_2S and CO_2 and may not be able to produce pipeline specification gas for some low pressure gas streams. The degradation products of DEA are much less corrosive than those of MEA. As mentioned by Polasek and Bullin (1994), DEA is not reclaimable in most units because at atmospheric pressure it decomposes below its boiling point and vacuum reclaimer had proved operationally unreliable. The heat of reaction for DEA with CO_2 is 653 BTU/lb, which is about 25% less than for MEA.

- **Diglycolamine (DGA)**

DGA is generally used as a 50 to 70 weight % solution in water. As with MEA, the corrosion problems with DGA prevent solution loadings above 0.35 mole/mole. DGA has a tendency to preferentially react with CO_2 over H_2S. DGA has some definite advantages over the other amines in that higher DGA concentrations in the solution result in lower circulation rates and also in lower freezing points. However, DGA has high heat of reaction for CO_2 at 850 BTU/lb.

- **Methyldiethanolamine (MDEA)**

MDEA is commonly used in the 20 to 50 weight % range. Lower weight % solutions are typically used in very low pressure, high selectivity applications such as SCOT tail gas cleanup unit. Due to considerably reduced corrosion problems, acid gases loading as high as 0.7 to 0.8 mole/mole are practical in carbon steel equipment. MDEA has distinct advantages over primary and

secondary amines which include lower vapor pressure, lower heats of reaction of CO_2 (600 BTU/lb), higher resistance to degradation, fewer corrosion problems and selectivity towards H_2S in the presence of CO_2 (Blanc et al., 1982).

- **Piperazine (Pz)**

The addition of piperazine, as activator for MDEA, increased the solubility of CO_2 in the region of low CO_2 partial pressure compared to pure MDEA. The CO_2 loading increased with decreasing temperature, increasing CO_2 partial pressure, and increasing Pz concentration (Si Ali and Aroua, 2004). Bishnoi and Rochelle (2002) claimed that the rate constant of Pz with CO_2 is an order of magnitude higher than that of conventional carbamate formers such as monoethanolamine (MEA).

- **Mixed Amines**

Mixtures of amines are generally mixtures of MDEA and DEA or MEA and are used to enhance CO_2 removal by MDEA, as described by Polasek, Bullin and Iglesias-Silva (1992). Such mixtures are referred to as MDEA-based amines with DEA or MEA as the secondary amine. The secondary amine generally comprises less that 20% of the total amine on a molar basis. Amine mixtures are particularly useful for lower pressure applications since the MDEA becomes less capable of picking up sufficient CO_2 to meet pipeline specification at lower pressure. At higher pressure, amine mixtures appear to have little or no advantage over MDEA (Polasek et. al, 1992). Mixed amines are also useful for cases where the CO_2 content of the feed gas is increasing over time due to field aging. Operating problems associated with mixed amines are determining and maintaining amine mixture concentration.

2.4 Reaction Mechanism

Zwitterion mechanism was originally proposed by Caplow and reintroduced by Danckwerts was accepted as the reaction for the carbamate formation between CO_2 with primary and secondary alkanolamine. The carbamate formation occurs when CO_2 reacts with alkanolamines. Protonated amine is also formed.

$$CO_2 + 2R_1R_2NH \leftrightarrow R_1R_2NCOO^- + R_1R_2NH_2^+ \quad (1)$$

Where R_1 is an alkyl and R_2 is H for primary amines and alkyl for secondary amines.

1. The first step of the mechanism reaction is the formation of zwitterions.

$$CO_2 + 2R_1R_2NH \underset{k_{-1}}{\overset{k2}{\leftrightarrow}} R_1R_2NCOO^- \quad (2)$$

2. Base-catalyzed deprotonation of the zwitterions by any base existing in the solution. This base could be amine, OH^- or H2O.

$$R_1R_2NH^+COO^- + B \xrightarrow{k_b} R_1R_2NCOO^- + BH^+ \quad (3)$$

The responding reactions are as follows:

$$R_1R_2NH^+COO^- + R_1R_2NH \xrightarrow{K_{AMINE}} R_1R_2NCOO^- + R_1R_2NH_2^+ \quad (4)$$

$$R_1R_2NH^+COO^- + H_2O \xrightarrow{K_{H2O}} R_1R_2NCOO^- + H_3O^+ \quad (5)$$

$$R_1R_2NH^+COO^- + OH^- \xrightarrow{K_{OH^-}} R_1R_2NCOO^- + H_2O \quad (6)$$

3. Dankwerts derived the forward reaction rate equation at steady state as:

$$r_{CO2-amine} = \frac{k_{2,R1R2NH}[CO_2][R_1R_2NH]}{1 + \frac{K_{-1}}{K_{H20}[H_2O] + K_{OH^-}[OH] + K_{R1R2NH}[R_1R_{2NH}]}} \quad (7)$$

4. For normal primary and secondary amines such as MEA and DEA, the carbamates formed (reaction 1) are quite stable. In the case of a hindered amine, such as MDEA, the carbamate formed is unstable and thus it undergoes carbamate reversion reaction. This condition is due to sterric effects that influence the stability of the carbamate formed by the amine with CO_2. According to Savori and Savage, due to the instability of the hindered amine, these readily undergo hydrolysis forming bicarbonate and releasing free amine again reacts with CO_2 thus leading to a stoichiometric loading capacity of 1 mol CO_2/ mol amine with appreciable rate of reaction.

5. Apart from above reactions, CO_2 also reacts in aqueous solution which consists of hydration of CO_2 and the bicarbonate formation:

   a. Hydration of CO2 (8)

   $CO_2 + H_2O \leftrightarrow HCO_3^- + H^+$ (slow)

   b. Bicarbonate formation (9)

   $CO_2 + OH^- \leftrightarrow HCO_3^-$

   The hydration of CO2 reaction is very slow and according to Blauwhoff, Versteed and Van Swaaj it may usually be neglected. However the bicarbonate reaction is fast and can enhance mass transfer even though the concentration of hydroxyl is low.

6. Due to chemical reaction between CO_2 and amines, neither the free-gas solubility nor the diffusivity of CO_2 in amine solutions can be measure directly.

In experiments done by Wang and Li to study the kinetics absorption of CO_2 into aqueous solution of 2-amino-2-methyl-1-propanol and diethanolamine, N_2O analogy was used to determine the diffusion coefficient of CO_2 in aqueous AMPD solutions. The N_2O analogy has been frequently used to estimate the solubility and diffusivity in amine solutions. Henry's Law constant and diffusion coefficient in aqueous AMPD was calculated by utilizing solubility and diffusivity if N_2O and CO_2 in water.

$$\left(\frac{H_{CO2}}{H_{N20}}\right)_{AMPD} = \left(\frac{H_{CO2}}{H_{N20}}\right)_{H20} \qquad (10)$$

$$\left(\frac{D_{CO2}}{D_{N2O}}\right)_{AMPD} = \left(\frac{D_{CO2}}{D_{N20}}\right)_{H20}$$

7. Versteeg and Van Swaaj proposed, based in available data of solubility and diffusivity of N_2O and CO_2 in water, four convenient equations are as follows:

$$H_{N20}(kPa.m^3.kmol^{-1}) = 8.5470x10^6 x\exp(-2284/T(K)) \qquad (11)$$

$$H_{CO2}(kPa.m^3.kmol^{-1}) = 2.82490x10^6 x\exp(-2044/T(K)) \qquad (12)$$

$$D_{N20}(m^2.s^{-1}) = 5.07x10^{-6} x\exp(-2371/T(K)) \qquad (13)$$

$$D_{co2}(m^2.s^{-1}) = 2.35x10^{-6} x\exp(-2119/T(K)) \qquad (14)$$

8. Equations (11) to (14) are widely applied in previous study to calculate the corresponding solubility and diffusivity of CO_2 in amine solution. Thus, this analogy could also be applied in the experiment to study the CO_2 absorption in aqueous alkanolamines and the blends of amines, specifically in the solubility of CO_2.

CHAPTER 3

METHODOLOGY

3.1 Flowchart of Tasks

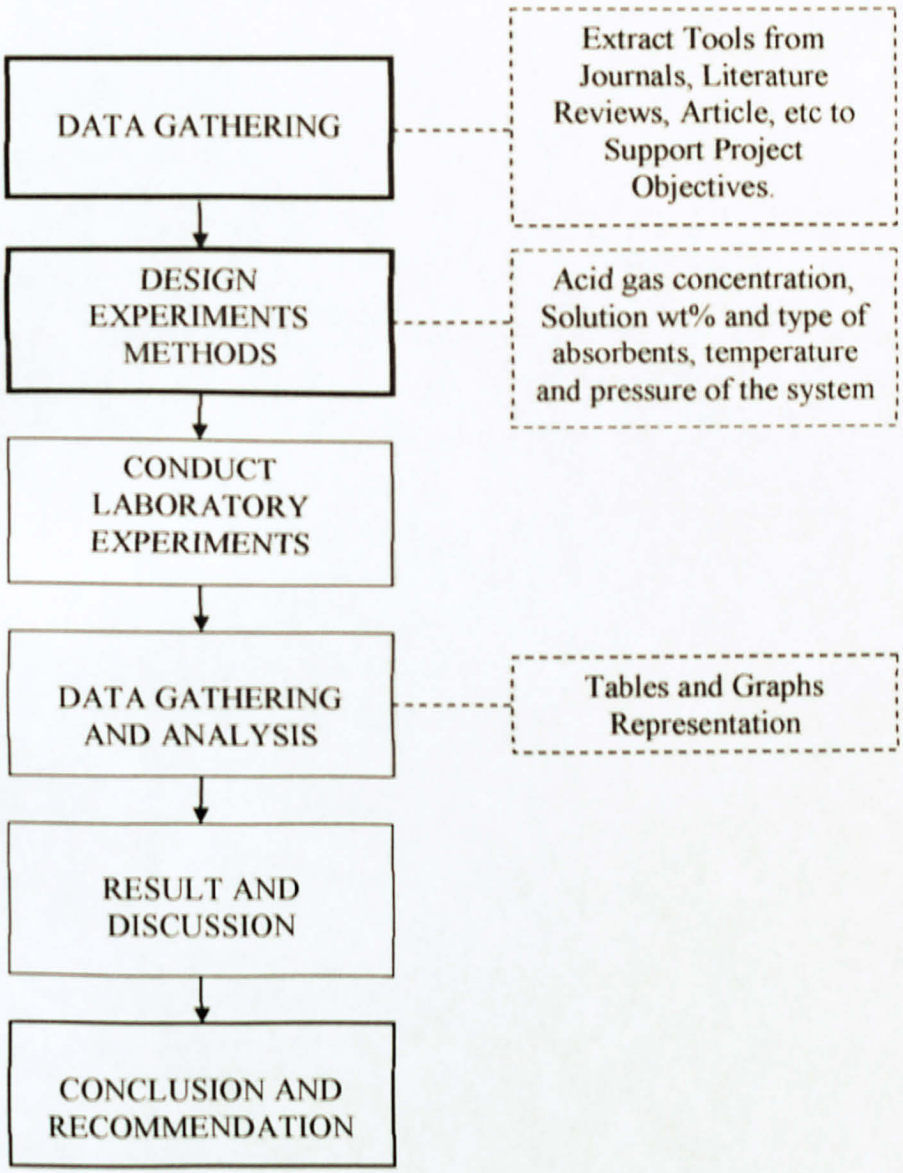

Figure 3.1: Flowchart for FYP 1 Project

The ***figure 3.1*** above represents the procedure need to be conducted to fulfill the project objectives.

3.2 Experimental Set Up

The selection of amine for gas sweetening is complex and must be based on several process considerations. For this project, it is important to have supporting data to match the objectives and theories stated. To fulfill this requirement, an experiment set up is necessary to conduct experiment on the solubility of carbon dioxide in mixtures of amine based compounds. The results obtained will be explained through various graphs, example CO_2 partial pressure (kPa) versus CO_2 loading ratio. Results gathered will be analyzed together with successful work of Jou et al, Kuranov et al, Macgregor et al and many more.

3.2.1 Equipment Description

SOLTEQ High Pressure Gas Solubility Cell (Model: BP22) has been designed for measurements of gas solubility of CO_2, SO_2, H_2S, NOx and constituents of natural gases such as methane, ethane, propane and butane in water, amine and alkaline solutions. The unit is capable of operating up to a pressure of 65 bar and temperature of 300°C. Complete instrumentations are provided to monitor all process parameters, which are linked to a data acquisition system. For gas and liquid composition analysis, a gas chromatograph and liquid titrator with auto sampler are incorporated in the unit.

The unit is capable of carrying out the following experiments:

- Determination of solubility of gases in various liquids
- Effect of temperature on the component solubility
- Effect of pressure on the component solubility
- Formation of methane hydrate and other complexes under high pressures

- Reduction of solubility after repeated solution-stripping cycle

The process flow diagram and assembly drawing for the high pressure gases solubility cell is provided in **Appendix A.**

3.2.2 Experimental Layout

The objective of this project is to study on the characteristics of CO_2 removal in natural gas using amine-based compound/ mixtures. The four different approaches are as follows:

c. Methyl Diethanolamine (MDEA) + Water (H_2O)
d. Methyl Diethanolamine (MDEA) + Diethanolamine (DEA) + Water (H_2O)
e. Methyl Diethanolamine (MDEA) + Piperazine (Pz) + Water (H_2O)
f. Methyl Diethanolamine (MDEA) + Diethanolamine (DEA) + Piperazine (Pz) + Water (H_2O)

The concentrations of the aqueous amine-based compound mixtures range from 30 wt% to 50 wt% in total. The solubility of CO_2 is measured up to 323.15 K with the partial pressure ranging from atmospheric pressure up to 10 bar. (*Refer **Table 3.1***)

Table 3.1: Experimental Layout

Exp. No.	MDEA (g)	DEA (g)	Pz (g)	H2O (g)	Total wt%	Temperature (°C)	Pressure (bar)
1	√	-	-	√	30	30-50	<10
2	√	-	-	√	50	30-50	<10
3	√	√	-	√	30	30-50	<10
4	√	√	-	√	50	30-50	<10
5	√	-	√	√	30	30-50	<10
6	√	-	√	√	50	30-50	<10

7	√	√	√	√	30	30-50	<10
8	√	√	√	√	50	30-50	<10

Samples of MDEA (purity >99 mass %), DEA (purity >99 mass %), Pz (purity >99 mass %) solutions are purchased from Merck. The CO_2 and N_2 gases are obtained from MOX gases. The purities of these gases vary from sources and batch number.

3.2.3 Preparing Amine Solution

The association of water with the MDEA molecule appears to be critical role of the tertiary amines, since Versteeg and Van Swaaij (1988) have shown that CO_2 does not react with MDEA in the absence of water. Water molecules dissolve MDEA through hydrogen bonding, and this association allows MDEA to catalyze the hydration of CO_2 as proposed by Barth et al. (1981).

The method to calculate 30wt% Methyl Diethanolamine, MDEA Solution is shown in the example below.

$$\frac{MDEA(g)}{MDEA(g)+H_2O(g)} = 0.3$$

$$MDEA = 3.00 grams, H_2O = 7.00 grams$$

Given
$\rho_{water@25^oC}$=0.9982g/ml
$\rho_{mdea@25^oC}$=1.041g/ml

$$7.00 g H_2O x \frac{1}{0.9982 \frac{g}{ml}} = 7.01 ml H_2O$$

$$3.00 g MDEA x \frac{1}{1.041 \frac{g}{ml}} = 2.9 ml MDEA$$

For preparing 30wt% MDEA solution of 200ml in total, the ratio of both the tertiary amine and water is needed. From the ratio, each of the volume required to prepare the mixture is known.

$$MDEA : H20 = 7.01 : 2.9 \rightarrow simplify$$

$$\frac{MDEA}{H20} : \frac{H20}{H20} = 2.4 : 1.0$$

$$Volume of MDEA(ml) = \frac{2.4}{3.4} x200ml = 141.2$$

$$Volume of H20(ml) = \frac{1.0}{3.4} x200ml = 58.8$$

As a result, 141.2 ml of MDEA mixed with 58.8ml of H_2O to produce 30wt% MDEA solution of 200ml in total.

3.2.4 Operating BP Model 22

Below is the simplified procedure for operating the system. Complete descriptions of the operating and experimental procedures are found in Appendix B.

1. Set N_2 and CO_2 pressure at respective gas cylinders
   Outlet (Right) $P_{CO2} = P_{N2} = 10$ bar
   Inlet (Left) $P_{CO2} = P_{N2} = 50 \sim 100$ bar
2. Switch main switch on mother board
3. Log in computer.
4. Press P2,M2 on mother board
5. Open valve V30, V31. not V32
6. Switch on temp bath. Set temperature.

PURGING MIXING CELL & SOLUBILITY CELL (with N_2)

7. Open V22 and V19. V15 Closed.
8. On computer, click on left side of screen, Set FIC-13 = 10L/min and press send.
9. Purge the unit by opening VA.
10. If flow rate is too high, change to 5L/min or 7L/min.
11. Purge for 5-10 minutes. pressure at solubility cell will indicate increment.
12. Press off. And close V22 and VA.

EVACUATION

13. V19 remains open.
14. Switch on vacuum box
15. Open V24
16. Start vacuuming.
17. Stop until pressure solubility cell reaches vacuum = 0.004 bar
18. Then switch off.
19. Close V24

GAS BOOSTER (with CO_2)

20. Close V19
21. Open V1
22. On computer, click on left side of screen, Set FIC-01 = 6L/min
23. Press send
24. Open V13,V14 and blue head (in order)
25. Since desired operating pressure is 1bar. Increase P of mixing vessel to 1+5 = 6 bar.
26. Press off
27. Close blue head and V13, V14 (in order)

28. Close V1
29. Observe pressure mixing cell to be constant (round up to 2 decimal places)

SETTING UP SOLUBILITY CELL PRESSURE

30. When pressure in mixing cell is constant, open up V15 to allow CO_2 into solubility cell
31. Allow pressure in solubility cell to be higher than desired pressure. Let say 3 bar.
32. On computer, click on left side of screen. Enter on FIC-13 = 10L/min. Press send
33. Purge solubility cell using VA until pressure is reduce to 1.0 bar
34. Press off.
35. Go to data logging on computer. And set for 0.5 minutes or 0.2 minutes. Press record.
36. Stop recording when the sol. Cell pressure on screen is constant.
37. Save recording data.

CO_2 ABSORPTION USING SOLVENT

For NEW SOLVENT

38. Open with appropriate driver. And use apparatus to suck remaining solvent. Repeat until liquid appears in the apparatus.
39. Assemble back all equipment.

For SAME SOLVENT

40. Dip transparent pipe into cylinder filled with solvent.(100ml)
41. On magnetic stirrer at 1100 rpm.
42. Simultaneously, open switch on metering pump and V16.

43. Simultaneously, close switch on metering pump and V16 after (min) 10ml or (max) 20ml.
44. On computer, record for 0.5 minutes until pressure of solubility cell remains constant.
45. To stop, press record. And save your readings.
46. Switch off magnetic stirrer.

WHEN PRESSURE SOL.CELL < 1 bar (PURGING)

47. Open V22 and V19.
48. On Computer, set FIC-13 = 5L/min. Press send.
49. Purge as usual until no more vapor/liquid comes out into beaker.
50. Press off when P>1 bar.
51. Close V22.

EVACUATION

52. Leave V19 Open.
53. Switch on vacuum box
54. Open V24
55. Start vacuuming.
56. Stop until P solubility cell reaches vacuum = 0.004 bar
57. Then switch off.
58. Close V24

FOR SHUTDOWN

59. Switch off magnetic stirrer M2 and Circulation Pump P3 on mother board.
60. Reduce the temp. set point to room temp. Allow the temperature to drop
61. Once temp has dropped, close V30 and V31.
62. Switch off control panel.

Return all valves to initial position

CHAPTER 4

RESULT AND DISCUSSION

Absorption is a physical or chemical phenomenon or a process in which atoms, molecules, or ions enter some bulk phase - gas, liquid or solid material. In this study, CO_2 is absorbed by aqueous alkanolamines which includes DEA, MDEA and PZ. For each batch of experiment, 20ml of amines mixtures is introduced into the solubility cell for absorption of CO_2 to take place. The initial partial pressure of CO_2 gases are set at 1 Bar, 3 Bar or 5 Bar with system temperature ranging from 30 – 50°C. The initial mole of CO_2 is calculated using Ideal Gas Law. CO_2 gases, in this case is assume to behave similar to ideal gas.

$$\boxed{PV = nRT}$$

Where;

P = Pressure (bar)

V = Volume (m^3)

n = Number of moles

R = Gas constant = 8.314×10^{-5} bar m^3 $moles^{-1}$ K^{-1}

T = Temperature (Kelvin)

The solubility equilibrium between the absorber and absorbent reaches when the partial pressure in the solubility cell remains constant. It is assume that the amine mixture is saturated with carbon dioxide gases, and that no more absorption between CO_2 and

amines can take place. When thermal equilibrium is reached, equilibrium pressure is recorded. Thermal equilibrium pressure is the sum of vapor pressure of water, amine-based compound and nitrogen partial pressure. In this case, all other pressure besides CO_2 is considered negligible or in a very small amount. To ensure the reliability of the experimental data, it is important that the concentration of amine in the solution for each experiment is maintained constant throughout each run.

The manipulated variables are the total weight percent of the total amines solution (30-50 wt %), partial pressure of carbon dioxide (1-5 bar) and system temperature (30-50°C). The fixed variables include initial CO_2 and amine mixtures concentrations, volume of amine mixtures being introduced to the system and the type of process (batch).

4.1 Experiment Data

A minimum of three trials was performed for each set of experiment. For each run, the observed parameters include system temperature, CO_2 partial pressure, breakpoint and duration for solubility equilibrium to occur. These parameters were observed through the usage of Process Flow Diagram (PFD) and Process Flow and Instrumentation Diagram (PNID) available from the LabView 8.2 Software. From the compiled data in ***table 4.1,*** the breakpoint and solubility graphs are prepared to analyze the trends for CO_2 absorption in various amines mixture and concentration.

Table 4.1: $C0_2$ loading in 30wt% MDEA solution at 30°C, 1 Bar

No	T(min)	P Total (bar)	P $C0_2$ (bar)	Moles, n $C0_2$ (initial)	mol CO_2/mol amine
1	0.5	1.19	1	0.000793921	0.00000
2	1	1.17	0.98	0.000778043	0.00002
3	1.5	1.16	0.97	0.000770103	0.00002
4	2	1.14	0.95	0.000754225	0.00004
5	2.5	1.13	0.94	0.000746286	0.00005
6	3	1.13	0.94	0.000746286	0.00005
7	3.5	1.13	0.94	0.000746286	0.00005
8	4	1.11	0.92	0.000730407	0.00006

9	4.5	1.1	0.91	0.000722468	0.00007
10	5	1.1	0.91	0.000722468	0.00007
11	5.5	1.08	0.89	0.00070659	0.00009
12	6	1.07	0.88	0.000698651	0.00010
13	6.5	1.07	0.88	0.000698651	0.00010
14	7	1.07	0.88	0.000698651	0.00010
15	7.5	1.06	0.87	0.000690711	0.00010
16	8	1.06	0.87	0.000690711	0.00010
17	8.5	1.05	0.86	0.000682772	0.00011
18	9	1.04	0.85	0.000674833	0.00012
19	9.5	1.04	0.85	0.000674833	0.00012
20	10	1.03	0.84	0.000666894	0.00013
21	10.5	1.03	0.84	0.000666894	0.00013
22	11	1.02	0.83	0.000658955	0.00013
23	11.5	1.02	0.83	0.000658955	0.00013
24	12	1.01	0.82	0.000651015	0.00014
25	12.5	1.01	0.82	0.000651015	0.00014
26	13	1	0.81	0.000643076	0.00015
27	13.5	1	0.81	0.000643076	0.00015
28	14	1.01	0.82	0.000651015	0.00014
29	14.5	0.99	0.8	0.000635137	0.00016
30	15	1	0.81	0.000643076	0.00015
31	15.5	0.99	0.8	0.000635137	0.00016
32	16	0.99	0.8	0.000635137	0.00016
33	16.5	0.99	0.8	0.000635137	0.00016
34	17	1	0.81	0.000643076	0.00015
35	17.5	0.99	0.8	0.000635137	0.00016
36	18	0.99	0.8	0.000635137	0.00016
37	18.5	0.98	0.79	0.000627198	0.00017
38	19	0.98	0.79	0.000627198	0.00017
39	19.5	0.98	0.79	0.000627198	0.00017
40	20	0.98	0.79	0.000627198	0.00017
41	20.5	0.98	0.79	0.000627198	0.00017
42	21	0.98	0.79	0.000627198	0.00017
43	21.5	0.98	0.79	0.000627198	0.00017
44	22	0.98	0.79	0.000627198	0.00017
45	22.5	0.98	0.79	0.000627198	0.00017
46	23	0.98	0.79	0.000627198	0.00017
47	23.5	0.97	0.78	0.000619258	0.00017
48	24	0.97	0.78	0.000619258	0.00017
49	24.5	0.96	0.77	0.000611319	0.00018
50	25	0.96	0.77	0.000611319	0.00018
51	25.5	0.97	0.78	0.000619258	0.00017
52	26	0.95	0.76	0.00060338	0.00019
53	26.5	0.96	0.77	0.000611319	0.00018
54	27	0.96	0.77	0.000611319	0.00018
55	27.5	0.97	0.78	0.000619258	0.00017
56	28	0.97	0.78	0.000619258	0.00017

57	28.5	0.97	0.78	0.000619258	0.00017
58	29	0.96	0.77	0.000611319	0.00018
59	29.5	0.96	0.77	0.000611319	0.00018
60	30	0.96	0.77	0.000611319	0.00018
61	30.5	0.96	0.77	0.000611319	0.00018
62	31	0.96	0.77	0.000611319	0.00018
63	31.5	0.96	0.77	0.000611319	0.00018
64	32	0.96	0.77	0.000611319	0.00018
65	32.5	0.96	0.77	0.000611319	0.00018
66	33	0.96	0.77	0.000611319	0.00018
67	33.5	0.96	0.77	0.000611319	0.00018
68	34	0.95	0.76	0.00060338	0.00019
69	34.5	0.95	0.76	0.00060338	0.00019
70	35	0.95	0.76	0.00060338	0.00019
71	35.5	0.95	0.76	0.00060338	0.00019
72	36	0.95	0.76	0.00060338	0.00019
73	36.5	0.95	0.76	0.00060338	0.00019
74	37	0.95	0.76	0.00060338	0.00019
75	37.5	0.95	0.76	0.00060338	0.00019
76	38	0.95	0.76	0.00060338	0.00019
77	38.5	0.96	0.77	0.000611319	0.00018
78	39	0.96	0.77	0.000611319	0.00018
79	39.5	0.96	0.77	0.000611319	0.00018
80	40	0.95	0.76	0.00060338	0.00019
81	40.5	0.96	0.77	0.000611319	0.00018
82	41	0.96	0.77	0.000611319	0.00018
83	41.5	0.96	0.77	0.000611319	0.00018
84	42	0.95	0.76	0.00060338	0.00019
85	42.5	0.95	0.76	0.00060338	0.00019
86	43	0.95	0.76	0.00060338	0.00019
87	43.5	0.95	0.76	0.00060338	0.00019
88	44	0.95	0.76	0.00060338	0.00019
89	44.5	0.95	0.76	0.00060338	0.00019
90	45	0.95	0.76	0.00060338	0.00019
91	45.5	0.95	0.76	0.00060338	0.00019
92	46	0.95	0.76	0.00060338	0.00019
93	46.5	0.95	0.76	0.00060338	0.00019
94	47	0.95	0.76	0.00060338	0.00019
95	47.5	0.94	0.75	0.000595441	0.00020
96	48	0.5	0.31	0.000246116	0.00055
97	**48.5**	**0.94**	**0.75**	**0.000595441**	**0.00020**
98	49	0.94	0.75	0.000595441	0.00020
99	49.5	0.94	0.75	0.000595441	0.00020
100	50	0.94	0.75	0.000595441	0.00020
101	50.5	0.94	0.75	0.000595441	0.00020
102	51	0.94	0.75	0.000595441	0.00020
103	51.5	0.94	0.75	0.000595441	0.00020
104	52	0.94	0.75	0.000595441	0.00020

105	52.5	0.94	0.75	0.000595441	0.00020
106	53	0.94	0.75	0.000595441	0.00020
107	53.5	0.94	0.75	0.000595441	0.00020
108	54	0.94	0.75	0.000595441	0.00020
109	54.5	0.94	0.75	0.000595441	0.00020
110	55	0.94	0.75	0.000595441	0.00020
111	55.5	0.94	0.75	0.000595441	0.00020
112	56	0.94	0.75	0.000595441	0.00020
113	56.5	0.94	0.75	0.000595441	0.00020
114	57	0.94	0.75	0.000595441	0.00020
115	57.5	0.94	0.75	0.000595441	0.00020
116	58	0.94	0.75	0.000595441	0.00020
117	58.5	0.94	0.75	0.000595441	0.00020
118	59	0.94	0.75	0.000595441	0.00020
119	59.5	0.94	0.75	0.000595441	0.00020
120	60	0.94	0.75	0.000595441	0.00020

Table 4.1 shows the performance using 30wt% methyl diethanolamine solution, operated at 30°C at a total pressure of 1 bar. 20 ml of the 200ml prepared solution were pumped into the solubility cell and is mixed with an initial concentration of 0.00079 moles of carbon dioxide. The magnetic stirrer enhanced the mixing process further. The initial and final concentration of CO_2 is obtained using the ideal gas law. As it is a batch process, the reaction between the amine solution and carbon dioxide is left to run until solubility equilibrium is reached, that is when the partial pressure remains constant.

The initial partial pressure in the solubility cell is at 1 bar, which is the total pressure of carbon dioxide gas. However, after introducing 20ml of amine solution into the system, the pressure increases up to 1.19 bar due to the vapor pressure of amine. Fang-Yuan Jou et al. (1994) mentioned that in order to calculate the partial pressure of CO_2 in N_2/CO_2 gas mixture, the vapor pressure of the amine solution must be subtracted from the total pressure. Therefore, neglecting the vapor pressure of amine, we take the total initial partial pressure of 1 bar.

Based on the data, the solubility equilibrium is reached at minute 48.5 with carbon dioxide partial pressure of 0.75 bar. The system has reached its breakpoint at minute 48.5. Beyond minute 48.5, there is no more absorption between CO_2 and amine mixture. The moles of carbon dioxide drop to 0.00059 moles compare to the initial at 0.00079

moles. As a result, the carbon dioxide loading is calculated to be 0.00020 moles CO_2/mol Methyl Diethanolamine. The experiments are conducted for more trials and the average result was taken to create the breakpoint and solubility graphs. Experiments are also repeated using different amines mixtures with varied solution concentration, temperature and pressure. A complete set of results are displayed in ***appendix C.***

4.2 Break Point Graphs at Total Pressure of 1 Bar

The break point graphs determine the solubility equilibrium of each experiment (break point) and analyze the CO_2 loading in various amines mixtures. From the breakpoint graph, the trend and rate of CO_2 absorption in amines mixtures can be further understood.

4.2.1 Methyl Diethanolamine (MDEA) Solution

The breakpoint graphs below represents the capability of CO_2 absorption onto single amines, operated at 30°C – 50°C and 1 Bar.

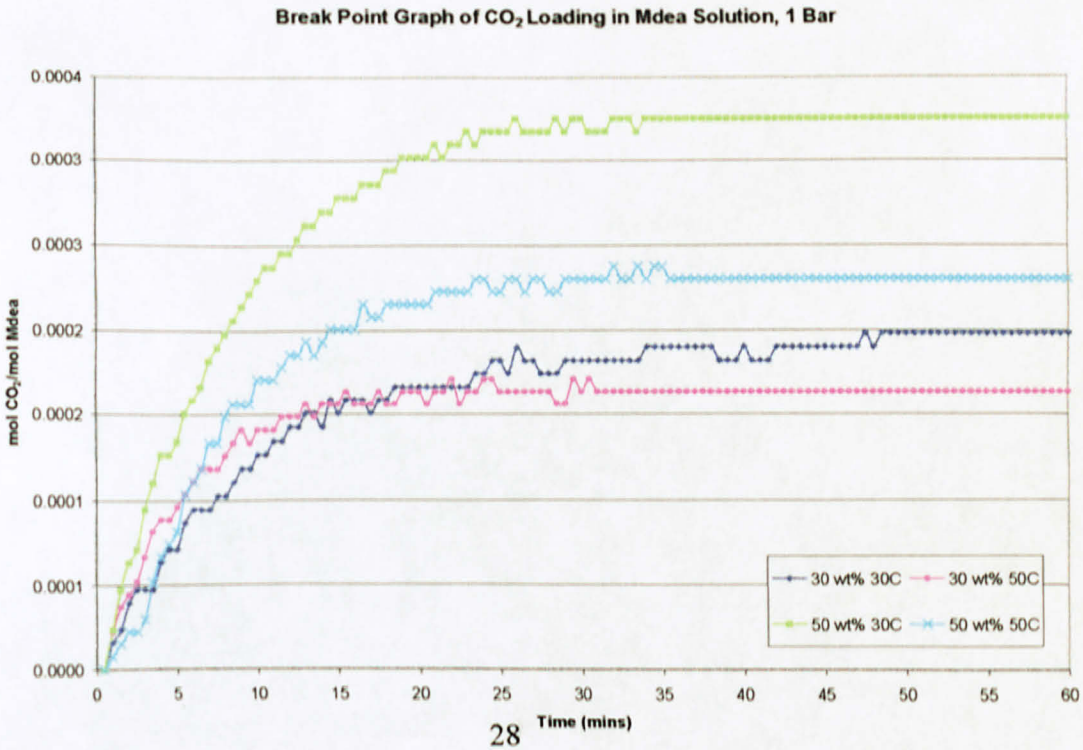

Figure 4.1: Break Point Graph of CO_2 Loading in MDEA Solution, 1 Bar

Figure 4.1 shows the carbon dioxide loading (mol CO_2/mol amine) versus time (minutes) for a solution mixture of methyl diethanolamine (MDEA) operated at different concentration and temperatures. The concentrations of solution range from 30 wt% up to 50 wt%, while the temperatures are played around 30°C to 50°C. The partial pressure of the system is operated at 1 Bar.

As observed, the line representing 50 wt% MDEA Solution operated at system temperature of 30°C or marked as *"50wt%30°C"* provides us with the highest CO_2 loading at approximately 0.00033 mol $C0_2$/mol amine. It clearly shows that solubility equilibrium is reached at minute 35 and beyond. For a lower solution concentration at 30wt%, operating at 30°C, it gives us a lower CO_2 loading at 0.00018 mol $C0_2$/mol amine. The solubility equilibrium is achieved at minute 49 and beyond. Theoretically, it should take lesser time to achieve solubility equilibrium since a lower amine concentration is used. Experiment conducted at a higher temperature (50wt%50°C) yields a lower CO_2 loading at 0.00023 mol CO_2/mol amine compared to at 30°C. The break point for 50wt%50°C is at minute 36 while the break point for 30wt%50°C is at minute 30, with a CO_2 loading of 0.00016 mol CO_2/ mol amine.

4.2.2 Methyl Diethanolamine+Diethanolamine Solution

Figure 4.2 below shows the carbon dioxide loading (mol CO_2/mol amine) versus time (min) for a solution mixture of methyl diethanolamine + diethanolamine operated at different concentration and temperatures. The concentrations of solution range from 30 wt% up to 50 wt%, while temperatures are played around 30°C to 50°C. The partial pressure of the system is operated at 1 bar.

The highest CO_2 loading, which is 0.00046 mol CO_2/mol MDEA+DEA occurred at minute 40 and beyond, represented by the line marked 50wt%30°C. This CO_2

loading is slightly higher than using only 50wt% MDEA solution at 30°C by an increment of 28.0%. At 30wt%30°C, the CO_2 loading accumulates up to 0.00044 mol CO_2/mol MDEA+DEA, reaching break point at minute 55 and beyond. At a higher absorption temperature of 50°C, 50wt% MDEA+DEA solution yields a higher CO_2 loading than 30wt% MDEA+DEA solution by 14.0%. The break point for 30wt%50°C is at minute 39.0 while for 50wt%50°C is at minute 52.0. For all representative trends, the rate of CO2 absorption is the fastest at the initial and gradually decreases as solubility equilibrium is reached.

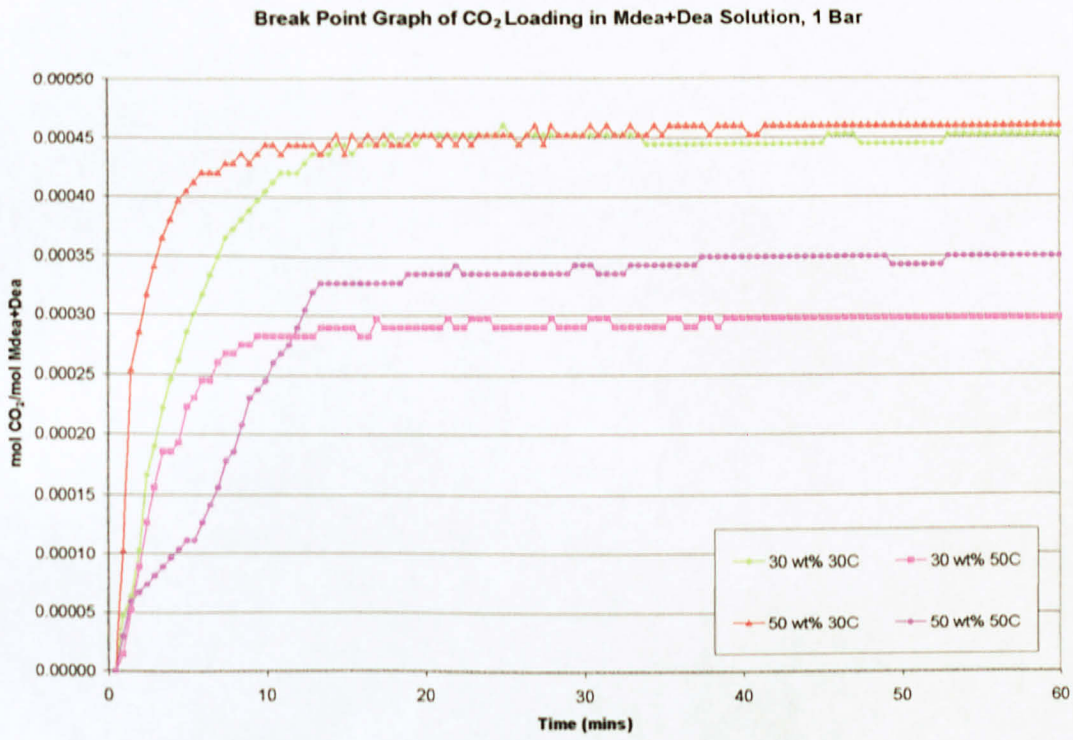

***Figure 4.2*: Break Point Graph of CO_2 Loading in MDEA+DEA Solution**

4.2.3 Methyl Diethanolamine+Piperazine Solution

Figure 4. 3 below shows the carbon dioxide loading (mol CO_2/mol amine) versus time (min) for a solution mixture of methyl diethanolamine + piperazine operated at different concentration and temperatures. The concentrations of

solution range from 30 wt% up to 50 wt%, while temperatures are played around 30°C to 50°C. The partial pressure of the system is operated at 1 bar.

At a solution concentration of 50 wt%, operated at 30°C, it gives the highest CO_2 loading of 0.0004 mol CO_2/ mol MDEA+Pz with break point at minute 35. The second highest CO_2 loading occurred at the same temperature but at a lower MDEA+Pz solution concentration of 30 wt%. At 50 wt% 50°C, the CO_2 loading is at 0.00033 mol CO_2/ mol MDEA+Pz with break point at minute 48. At the same temperature of 50°C but at a lower solution concentration of 30 wt%, the CO_2 loading drops to 0.00029 mol CO_2/ mol MDEA+Pz with break point at 32 minute.

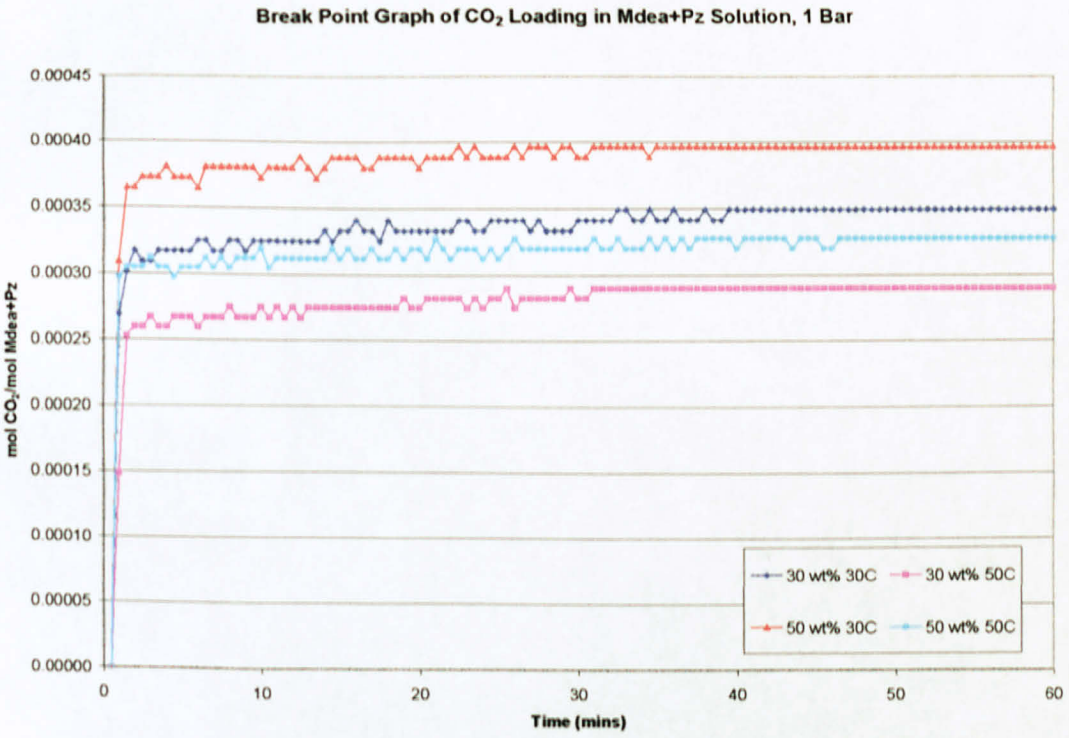

Figure 4.3: Break Point Graph of CO_2 Loading in MDEA+Pz Solution, 1 Bar

4.2.4 Methyl Diethanolamine+Diethanolamine+Piperazine Solution

Figure 4.4-4.5 below shows the carbon dioxide loading (mol CO_2/mol amine) versus time (min) for a solution mixture of methyl diethanolamine + diethanolamine + piperazine operated at different concentration and temperatures. The concentrations of solution range from 30 wt% up to 50 wt%, while temperatures are played around 30°C to 50°C. The partial pressure of the system is operated at 1 bar.

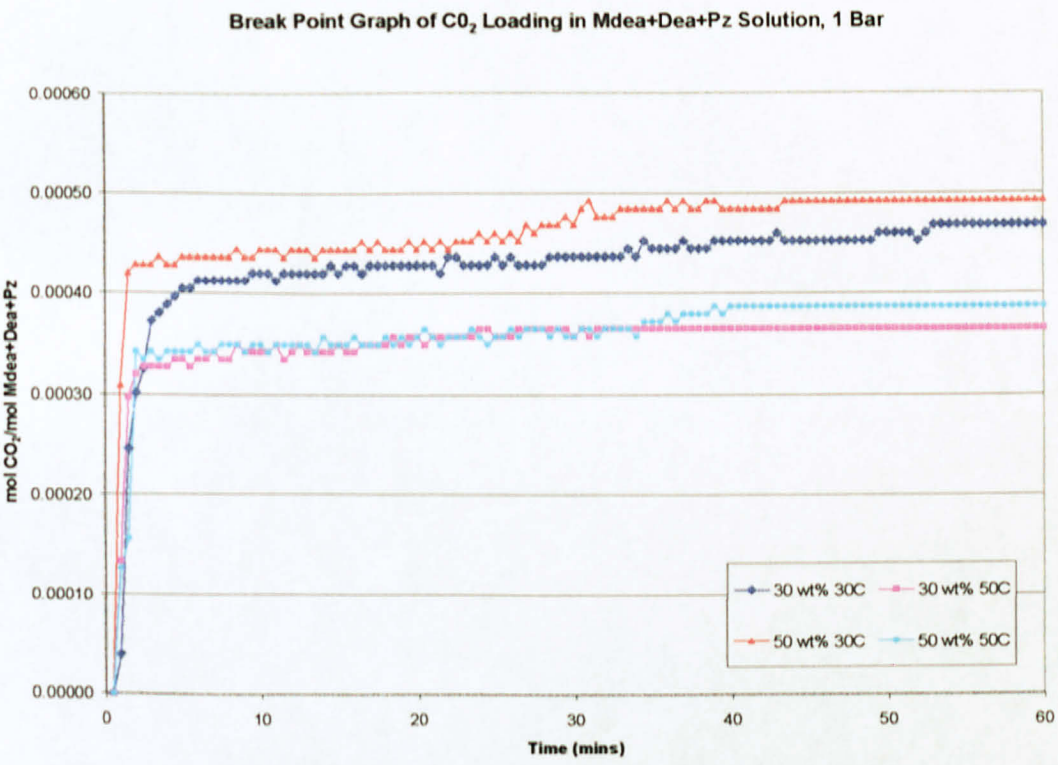

Figure 4.4: Break Point Graph of CO_2 Loading in MDEA+DEA+Pz Solution, 1 Bar

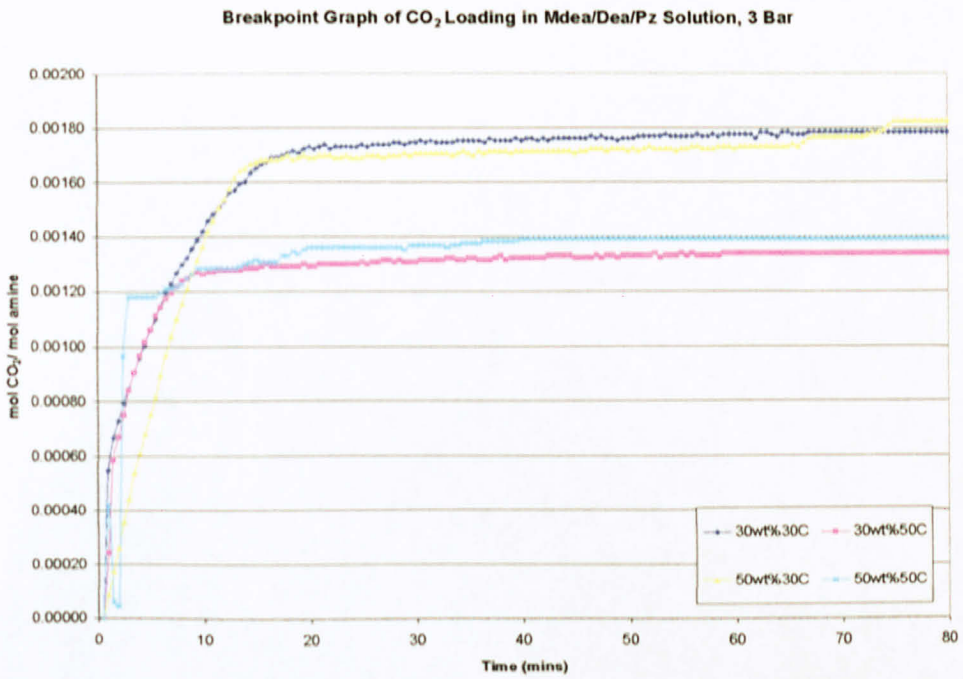

Figure 4.5: Break Point Graph of CO_2 Loading in MDEA+DEA+Pz Solution, 3 Bar

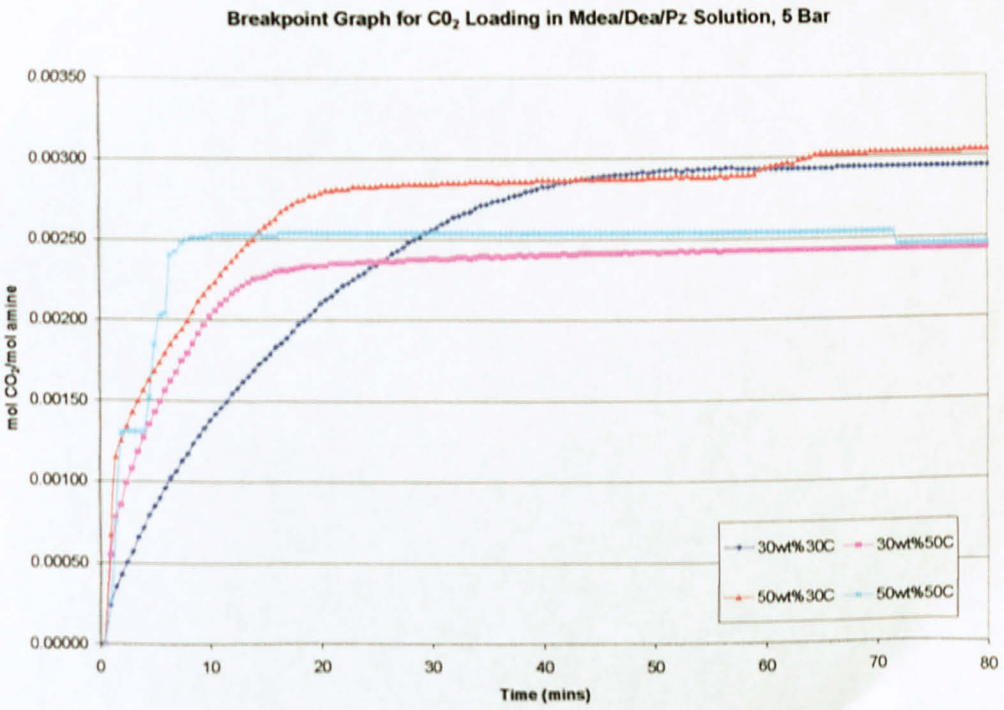

***Figure 4.6*: Break Point Graph of CO_2 Loading in MDEA+DEA+Pz Solution, 5 Bar**

For ***figure 4.4***, the highest CO_2 loading, which is 0.00049 mol CO_2/mol MDEA+DEA+Pz occurred at minute 43 and beyond, represented by the line marked 50wt%30°C. This CO_2 loading is higher compared to using only 50wt% MDEA+DEA solution at 30°C by an increment of 10.0% and 18.0% increment at 50 wt% MDEA+Pz solution at similar temperature and pressure. At 30wt%30°C, the CO_2 loading accumulated up to 0.00047 mol CO_2/mol MDEA+DEA+Pz, reaching break point at minute 52 and beyond. At a higher absorption temperature of 50°C, 50wt% MDEA+DEA+Pz solution yields a higher CO_2 loading than 30wt% MDEA+DEA+Pz solution by 8.0%. The break point for 30wt%50°C is at minute 32.0 while for 50wt%50°C is at minute 42.0.

Since the main focus of the study is to comprehend the mixture that provides the best CO_2 loading, experiments are repeated at a higher pressure for the tertiary mixtures of amines. At a higher pressure of 3 bar and 5 bar (refer ***figure 4.5*** and ***figure 4.6***), the CO_2 loading increases from 0.00049 mol CO_2/ mol amine to 0.00185 mol CO_2/ mol amine and to 0.00300 mol CO_2/mol amine respectively, using CO_2 loading at 1 Bar as base. Similar to interpretation made for figure 4.3, the highest CO_2 loading occurred at 50wt% amine concentration and system temperature of 30°C. For 50wt% MDEA+DEA+Pz concentration, system temperature at 30°C and pressure of 3 Bar, the breakpoint is at minute 74. For 50wt% MDEA+DEA+Pz concentration, system temperature at 30°C and pressure of 5 Bar, the breakpoint is at minute 80. The difference in the duration for breakpoint is determined by process limitation – pressure, temperature and amine concentration. It takes longer time to reach solubility equilibrium for higher pressure, since the absorption allowances for CO_2 is greater.

4.3 Solubility Graphs and Discussion

4.3.1 CO_2 Loading for MDEA/ MDEA+DEA/ MDEA+Pz Solutions at 1 Bar

Figure 4.7 and ***4.8*** represents CO_2 absorption into various amines solution, measured at different concentrations and temperatures. The operated pressure is at 1 Bar. ***Figure 4.7*** illustrates the ability of CO_2 absorption into four different amine mixtures at 303.15K, 1 Bar. The final partial pressure versus CO_2 loading is plotted to determine which mixtures gives the best absorption capabilities. ***Figure 4.8*** illustrates the ability of CO_2 absorption into four different amine mixtures at 323.15K, 1 Bar. The final partial pressure versus CO_2 loading is plotted to determine which mixtures gives the best absorption capabilities. ***Figure 4.9*** summarizes the best result adapted from ***figure 4.7*** and ***figure 4.8***. ***Figure 4.9*** illustrates CO_2 loading at 50wt% amine solution at different temperatures, intending to show at which temperature and solution mixtures provides the best results. These figures are discussed in ***section 4.3.2.***

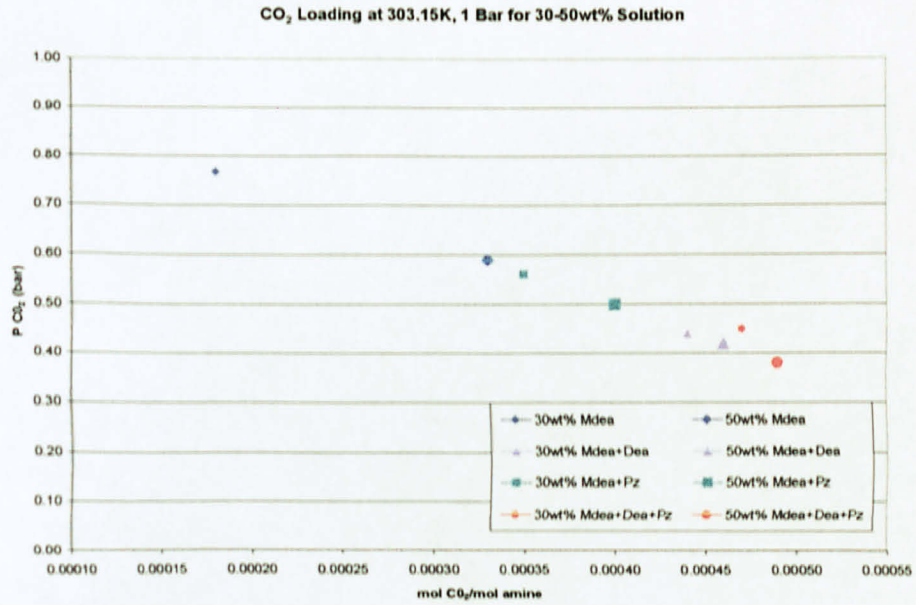

Figure 4.7: CO_2 Loading at 303.15K, 1 Bar for 30-50wt% Amine Solution

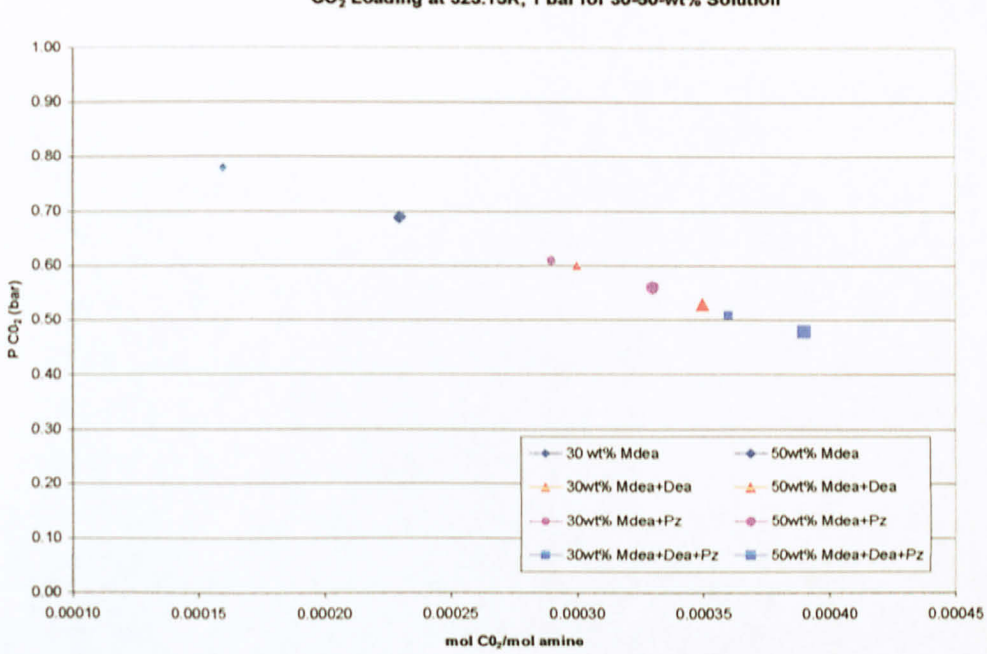

Figure 4.8: CO_2 Loading at 323.15K, 1 Bar for 30-50wt% Amine Solution

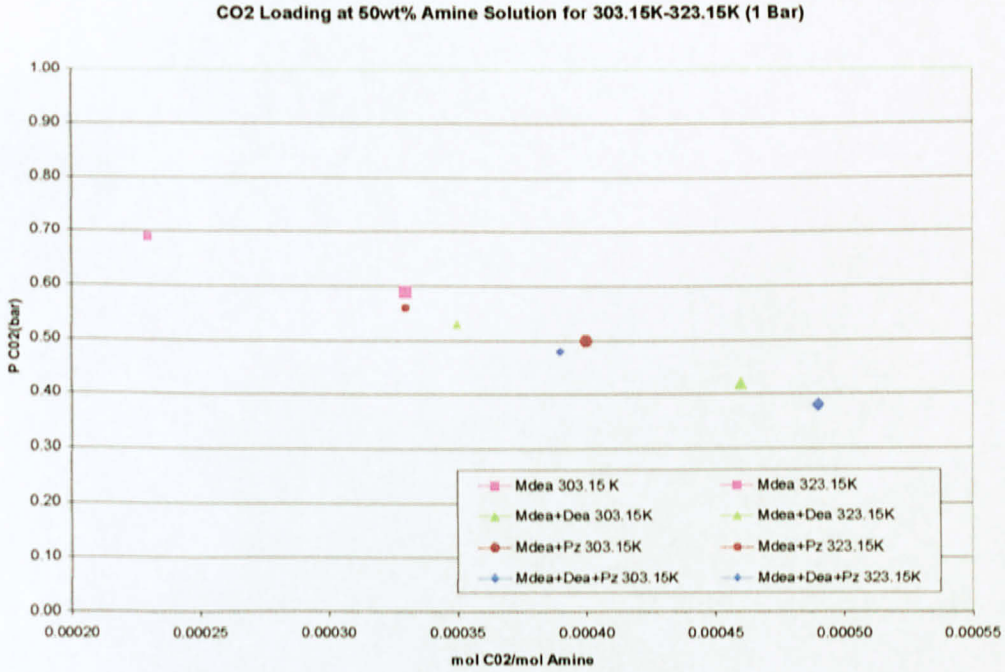

Figure 4.9: CO_2 Loading at 303.15K-323.15 K, 1 Bar for 50wt% Amine Solution

4.3.2 Discussion on CO_2 Absorption Capabilities in Various Amines Compounds

4.3.1.1 Absorption of CO_2 with Methyl Diethanolamine (MDEA)

In activated MDEA solutions, the CO_2 loading increases with CO_2 partial pressure and decreases with the absorption temperature. Based on Jong Sup Lee et al. (1997), MDEA needs to be maintained at a low concentration in order to increase the absorption capacity of CO_2 in aqueous MDEA solution. The experiment conducted by Jong Sup Lee et al. (1997) clarify below a CO_2 partial pressure of 10kPa, a 20.5 wt % MDEA solution showed a maximum absorption capacity of CO_2, and above 10kPa, a 50.0 wt % MDEA solution was superior. For this experiment, it was conducted at 1 bar (101.325 kPa). From the result obtained, it showed that CO_2 absorption gives a better performance at 50.0wt% solution compared to 30.0wt% at CO_2 partial pressure above 10kPa. This is aligned with the experimental result made by Jong Sup Lee at al. (1997). Referring to ***figure 4.7*** and ***figure 4.8***, it shows that CO_2 loading is at its greatest at higher amine concentration and at a lower temperature.

MDEA is commonly used in the 20 to 50 wt% range. Lower weight % solutions are typically used in very low pressure, high selectivity applications such as SCOT tail gas cleanup unit. Due to considerably reduced corrosion problems, acid gas loading as high as 0.7 to 0.8 mole/mole is practical in carbon steel equipment. MDEA has several advantages over primary and secondary amines which includes lower vapor pressure, lower heats of reaction, higher resistance to degradation, fewer corrosion problems and selectivity towards the presence of CO_2, which most have been reported by Blanc et al. (1982).

It should be mentioned, however, that since sterically hindered amines do not form stable carbamates (Sartori and Savage., 1983), the reaction between CO_2 and OH- may be the dominant reaction for the absorption of CO_2 into aqueous solutions of sterically hindered amines (Versteeg et al., 1990). In this case, the bicarbonate and carbonate ions may be presents in the solution in larger amounts than carbamate ions. Hence, the regeneration energy costs when aqueous solutions sterically hindered amines are used to absorb CO_2 is lower.

4.3.1.2 *Absorption of CO_2 with Methyl Diethanolamine + Diethanolamine Mixtures*

Mixtures of amines are generally mixtures of MDEA and DEA or MEA and are used to enhance the CO_2 removal by MDEA, as described by Polasek, Bullin, and Iglesias-Silva (1992). Such mixtures are referred to as MDEA-based amines with DEA or MEA as the secondary amine. MDEA-based mixtures are normally used to increase the CO_2 pickup in cases where the MDEA is allowing too much CO_2 slip overhead in the absorber. Spiking the MDEA with MEA or DEA to achieve the desired CO_2 pickup is often advantageous over a complete amine switch out to a DEA or MEA system because the MDEA regenerator reboiler may be undersized for DEA and MEA system.

In this experiment, 30-50 wt% solution of MDEA+DEA is used to determine the CO_2 solubility operated at different temperature and partial pressure of 1 bar. The results obtained agrees with the research conducted by Polasek, Bullin, and Iglesias-Silva (1992), which generates a higher CO_2 loading using mixtures of amine, instead of just MDEA solution. Using 50 wt% MDEA solution operated at 30°C, 1 Bar yields a CO_2 loading of 0.00033 mol CO_2/mol MDEA while at the same operating condition, a 50 wt% MDEA+DEA solution yields a CO_2 loading of 0.00046 mol CO2/mol MDEA+DEA. This shows that the CO_2 loading had an increment of 28.0%, compared when using a single amine.

However, the CO_2 pressure plays a very important role as it has strong affinity towards CO_2 loading for MDEA+DEA system.

For MDEA+DEA system, equilibrium loading decreases with temperature and increase with pressure, as described by Olukayode Fatai Dawodu and Axel Meisen (1994). ***Figure 4.7*** and ***figure 4.8*** indicates that higher CO_2 loading is found at a lower temperature of 30°C but at a higher solution concentration of 50wt%.

At low pressure, the influence of the primary or secondary amine is pronounced, resulting in CO_2 loadings that increase with DEA concentration but decrease with increasing MDEA concentration, for solutions of equal molarities. At higher CO_2 pressure, the stoichiometric loading limitation associated with the absorption of CO_2 into DEA hinders the absorption in the amine blends. In this region, MDEA solutions which have no stoichiometric limitations provide higher loadings than MDEA+DEA blends.

Amine mixtures are particularly useful for lower pressure applications since the MDEA becomes less capable of picking up sufficient CO_2 to meet pipeline specifications at lower pressure. At higher pressure, amine mixtures appear to have little or no advantageous over MDEA (Polasek et al. 1992).

4.3.1.3 Absorption of CO_2 with Methyl Diethanolamine + Piperazine Mixtures

Another important development in alkanolamine technology is the use of activated amine solutions which consists of a conventional amine doped with small amounts of an accelerator (activator) that enhances the overall CO_2 absorption rate. Piperazine (Pz) is one activator that has been the focus of many researchers. Based on B. Si Ali et al. (2004), the addition of piperazine, as activator for MDEA, increased the solubility of CO_2 in the region of CO_2 partial

pressure compared to pure MDEA. This is evidently proven from the experiment result conducted for MDEA and MDEA+Pz solution. (Refer ***table 4.2***)

Table 4.2: Comparison of CO_2 loading between MDEA and MDEA+Pz solution operated at 1 Bar

Solution	30 wt% 30°C	50 wt% 30°C	30 wt% 50°C	50 wt% 50°C
MDEA	**0.00018**	**0.00033**	**0.00016**	**0.00023**
MDEA+Pz	**0.00035**	**0.0004**	**0.00029**	**0.00033**

CO_2 Loading (mol CO_2/ mol amine)

However, based on the overall experimental results obtained, the CO_2 loading is much higher when a solution of MDEA+DEA is used, compared to both MDEA and MDEA+Pz solution. ***Figure 4.9*** illustrates that CO_2 loading increases in the range of MDEA<MDEA+Pz<MDEA+DEA, and gives best result at a higher solution concentration and lower temperature.

Despite having higher CO_2 loading in MDEA+DEA mixtures, Bishnoi and Rochelle (2002) claimed that a mixture of MDEA+Pz absorbs CO_2 faster than monoethanolamine (MEA) or diethanolamine (DEA) blends with MDEA at similar concentrations. This claimed is aligned with the experimental results obtained as shown below. (Refer ***table 4.3***)

Table 4.3: Summary of break point for MDEA+DEA and MDEA+Pz solution operated at 1 Bar

Solution	30 wt% 30°C	50 wt% 30°C	30 wt% 50°C	50 wt% 50°C
MDEA+DEA	**55**	**40**	**39**	**52**
MDEA+Pz	**38**	**35**	**32**	**48**

Break Point (minute)

The CO_2 loading increased with decreasing temperature, increasing CO_2 partial pressure, and increasing Pz concentration. The effect of piperazine concentration on the ultimate CO_2 loading was found to be dependent on both the CO_2 partial pressure and solution temperature. At high temperature and high CO_2 partial pressure, the addition of piperazine did not show any significant effect.

4.3.3 CO_2 Loading for MDEA+DEA+Pz Solutions at 1-5 Bar

Summarizing ***table 4.4*** *in section 4.3.2.1*, it is clear that tertiary mixtures of MDEA+DEA+Pz solution provides the greatest CO_2 absorption tendencies when operated at low temperature and high solution concentration. In this section, this tertiary system is tested at a higher pressure of 3 and 5 bar, while maintaining the range of temperature between 30°C to 50°C and solution concentration between 30wt% to 50wt%. The results are displayed in ***figure 4.10*** and ***figure 4.11*** and are discussed in *section 4.3.2.1.*

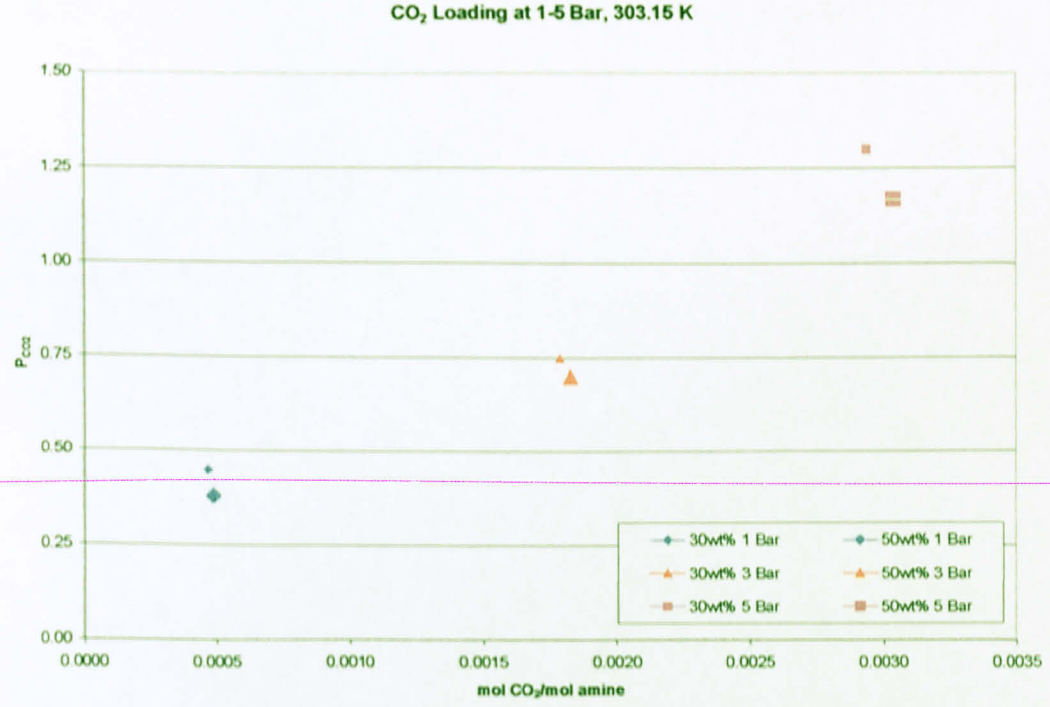

Figure 4.10: CO_2 Loading in 30-50wt% MDEA+DEA+Pz solutions at 303.15K, 1-5 Bar

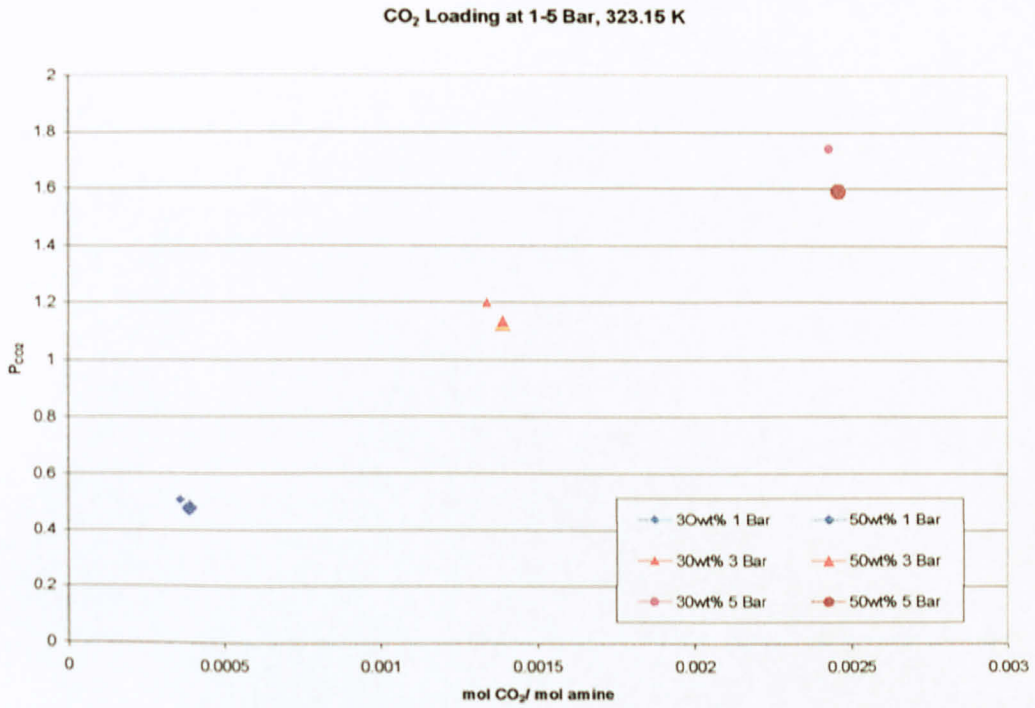

Figure 4.11: CO_2 Loading in 30-50wt% MDEA+DEA+Pz solutions at 323.15K, 1-5 Bar

4.3.2.1 *Absorption of CO_2 with Methyl Diethanolamine+ Diethanolamine + Piperazine Mixtures*

As suggested by Chakravarty (1985), in order to enhance the absorption rate of CO_2 and at the same time maintain the advantages of using MDEA, is to use **aqueous alkanolamine blends** consisting of a mixture of MDEA and a primary or secondary alkanolamine. However, for the final part of the experiment in ***Table 3.1***, a **new** aqueous alkanolamine blends consisting of MDEA+DEA+Pz is designed. Currently, there is neither literature review nor experimental analysis that has been conducted for this specific amines blend by researchers. Therefore,

discussion and conclusion is made by comparing the CO_2 loading found for MDEA/ MDEA+DEA and MDEA+Pz.

Table 4.4: Summary of CO_2 loading for different amine solutions operated at 1 Bar

Solution	30 wt% 30°C	50 wt% 30°C	30 wt% 50°C	50 wt% 50°C
MDEA	**0.00018**	**0.00033**	**0.00016**	**0.00023**
MDEA+DEA	**0.00044**	**0.00046**	**0.0003**	**0.00035**
MDEA+Pz	**0.00035**	**0.0004**	**0.00029**	**0.00033**
MDEA+DEA+Pz	***0.00047***	***0.00049***	***0.00036***	***0.00039***

CO_2 loading (mol CO_2/ mol amine)

Table 4.4 shows the summary of CO_2 loading for different amine solutions operated at CO_2 partial pressure of 1 bar. CO_2 loading will vary accordingly based on the type of amine mixtures, concentrations and operated temperature used. At this condition, the highest CO_2 loading occurs for MDEA+DEA+Pz solution mixtures at 0.00049 mol CO_2/ mol amine, and is followed by MDEA+DEA solution, MDEA+Pz solution and finally, with the least amount of CO_2 loading, the MDEA solution. The factors that contribute to the differences in CO_2 loading between these solutions are the *absorption kinetics*, *operated temperatures* and *pressures* and *solution concentrations*. This is clearly supported by the tabulated date found in ***figure 4.7, figure 4.8*** and ***figure 4.9.*** The highest CO_2 loading occurs at 50wt% MDEA+DEA+Pz solution at 30°C.

It is said that at a higher solution concentration, solubility of CO_2 into the amine mixtures are greater. This is because the opportunity for CO_2 reaction with carbamate ion is greater. However, the CO_2 loading is limited once the break point is reached, or when the amine solution is saturated with CO_2 gases.

CO_2 loading is the least for MDEA ($RRCH_3N$, where R refers to CH_2-CH_2OH) solution due to the reason that pure aqueous MDEA do not react with CO_2 directly because it lacks the N-H bond required to form carbamate ion with CO_2.

Therefore, the presence of CO_2 in aqueous solutions of these amines produces only bicarbonate and carbonate ions.

The contribution of each base to the overall reaction rate depends on both its concentration and strength. Although the contribution to the deprotonation of zwitterion in aqueous solution of mixed alkanolamine comes from MDEA, DEA, OH-, or H_2O, the contributions are mainly from MDEA and DEA. It is only to a lesser extent that they do come from OH- and H_2O. Addition of a sterically unhindered secondary alkanolamine to a purely physical solvent such as water increases the absorption capacity and rate manifold as mentioned by Daniel P. Hagwiesche et al (1994). Sterically unhindered secondary amines, DEA have the ability to form stable carbamate ions. This provides a higher CO_2 loading compared to when using pure aqueous MDEA.

The addition of piperazine, as activator for MDEA, increased the solubility of CO_2 in the region of low CO_2 partial pressure compared to pure MDEA. The CO_2 loading increased with decreasing temperature, increasing CO_2 partial pressure, and increasing Pz concentration (Si Ali and Aroua, 2004). Bishnoi and Rochelle (2002) claimed that the rate constant of Pz with CO_2 is an order of magnitude higher than that of conventional carbamate formers such as monoethanolamine (MEA).

Figure 4.10 and ***figure 4.11*** shows the trends between partial pressure of CO_2 against CO_2 loading in MDEA+DEA+Pz solution operated at different temperature, amine concentration and pressure. CO_2 loading increases with decrease temperature, increase partial pressure and increase solution concentrations. The capability of amines to absorb CO_2 at different partial pressure, temperature and concentrations are summarized in ***table 4.5.***

Table 4.5: CO_2 loading for MDEA+DEA+Pz Solution at 1-5 Bar

Solution	30 wt% 30°C	50 wt% 30°C	30 wt% 50°C	50 wt% 50°C
1 Bar	**0.00047**	**0.00049**	**0.00036**	**0.00039**

3 Bar	**0.00179**	**0.00183**	**0.00134**	**0.00139**
5 Bar	**0.00294**	***0.00304***	**0.00243**	**0.00246**

CO_2 loading (mol CO_2/ mol amine)

From ***table 4.5,*** the greatest CO_2 loading occurred at 5 bar, with solution concentration of 50wt% and temperature of 30°C. This mixture provides the greatest benefit in terms of low heat of reaction energy, high stability, high acid gas loading, greater ability to absorb CO_2, lower vapor pressure and higher resistance to degradation. Because of the high heat of reaction associated with carbamate formation, high regeneration energy costs are incurred. A tertiary alkanolamine, MDEA has a lower CO_2 absorption rate, but since the heat of reaction associated with bicarbonate and carbonate formation is much smaller, regeneration energy costs are lower.

In addition to the discussion, the enthalpy of solution of carbon dioxide in the amine solutions could be calculated by the application of Gibbs-Helmholtz equation:

$$\left[\frac{d \ln p}{d(1/T)}\right]_x = \frac{\Delta H}{R}$$

Where;

p = partial pressure (kPa)

T = temperature (°C)

ΔH = enthalpy of solution, kJ/mol CO_2

CHAPTER 5

CONCLUSION & RECOMMENDATION

The technology of using alkanolamines for removal of hydrogen sulfide and carbon dioxide from natural gases has been used for decades. Since the 1960's and 70's several amines have come into general use, however, limited information has been reported in the literature concerning the amine best suited to a particular service. Many amine units which are operating very inefficiently could be optimized by simply changing amines. In this study, absorption of CO_2 into aqueous alkanolamines is investigated using High Pressure Gas Solubility Cell (BP Model 22) at variation of temperature, pressure and concentration. The specific goal in this respect is to have solution of tertiary + secondary or tertiary + primary amines that retain much of the reactivity of primary or secondary amines, offer low regeneration costs, are less corrosive and require lower circulation rates to achieve a desired degree of sweetening. The results indicate that the influences of amine components and composition depend on the extent of substitution, temperature, and CO_2 partial pressure. Furthermore, the non additivity of solubilities based on single amine systems highlights the necessity for experimental determination of equilibrium loadings in blended amine systems. To achieve a certain CO_2 specification, it is important to consider the base or stock solution. If the amine is a secondary amine, such as DEA, attempts should be made to increase the amine concentration. Higher amine concentration increases CO_2 pickup. However care should be taken not to exceed corrosion limits. If single amine is used, increasing the amine concentration via an amine mixture is an alternative. Adding MDEA increases the amine concentration with higher corrosion limitations. Furthermore, with MDEA having a lower heat of absorption, problems with undersized boilers are unlikely. If the base stock is MDEA, then the only amine mixture to consider is with primary or secondary amine. These amines increase the CO_2 pickup but have higher heats of absorption than MDEA and tend to be more corrosive. Problems with undersized reboilers may result. Mixed amines

are also useful for cases where the CO_2 content of the feed gas is increasing over time due to field aging. Operating problems associated with mixed amines are determining and maintaining amine mixture concentration. At higher pressure, amine mixtures appear to have little or no advantage over MDEA (Polasek et. al, 1992). Chakravarty et al. (1985) first suggested mixing amines to capitalize on the advantage of each primary amine. By blending a sterically unhindered primary or secondary alkanolamine with a tertiary alkanolamine, bulk CO_2 removal is easily accomplished while regeneration energy costs are minimized. Mixture of MDEA+DEA+Pz provides the greatest tendency for CO_2 absorption compared to solution of tertiary, or tertiary plus primary or secondary solution. For this study, it is concluded that absorption of CO_2 into amines increases with concentrations, pressure and decreases with increased temperature.

CHAPTER 6
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CHAPTER 7
APPENDICES

Appendix A

- Process Flow Diagram (PFD) of High Pressure Gas Solubility Cell (Model BP 22)
- Bill of Material – Assembly Drawing
- Assembly Drawing
- Model BP 22 Component Specifications
- Instrumentation and Control
- Valves List
- Safety Considerations

Appendix B

- Operating Procedures
- Experiment Procedures

Appendix C

- Experimental Results

Appendix D

- Laboratory Experiment Images

Appendix A

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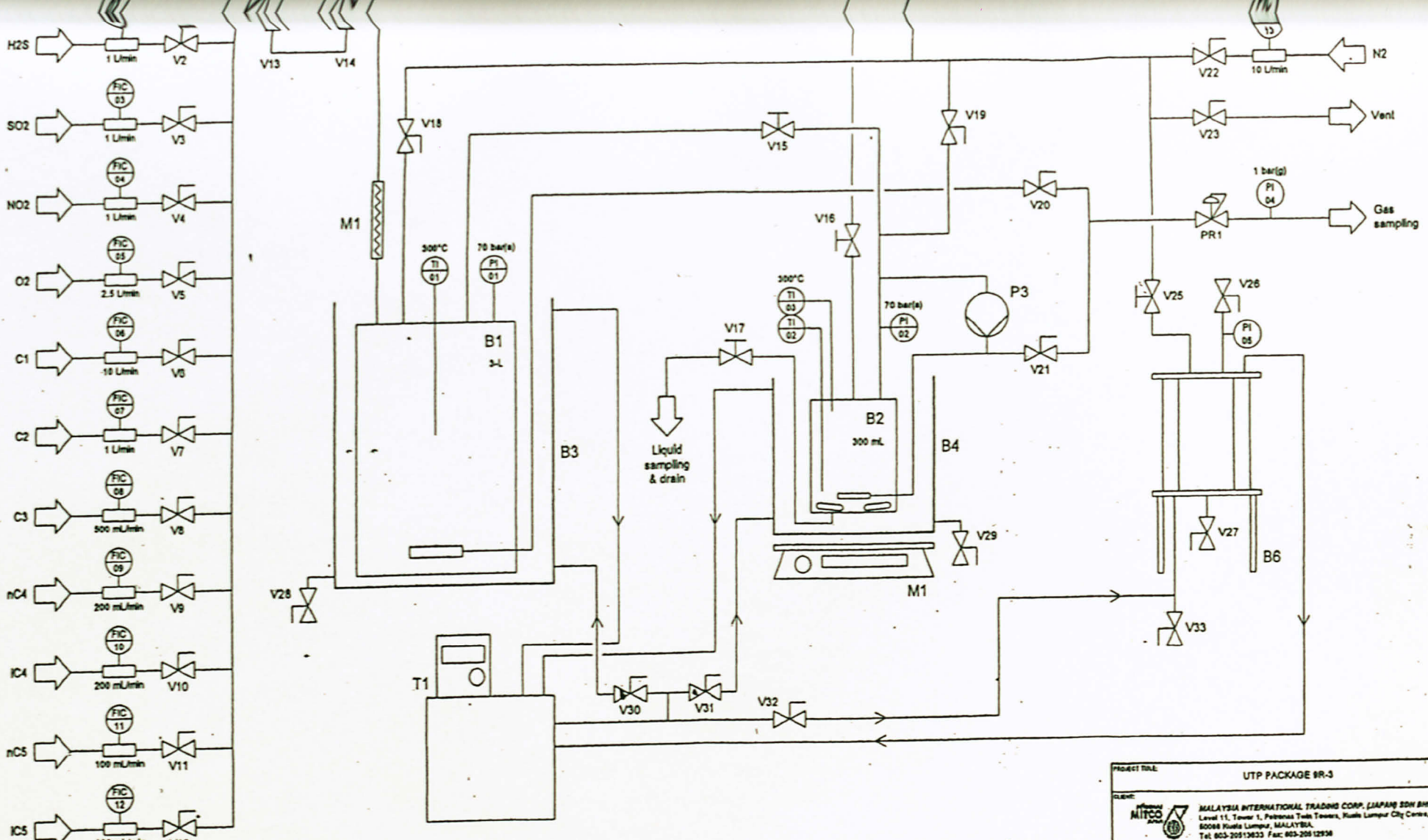
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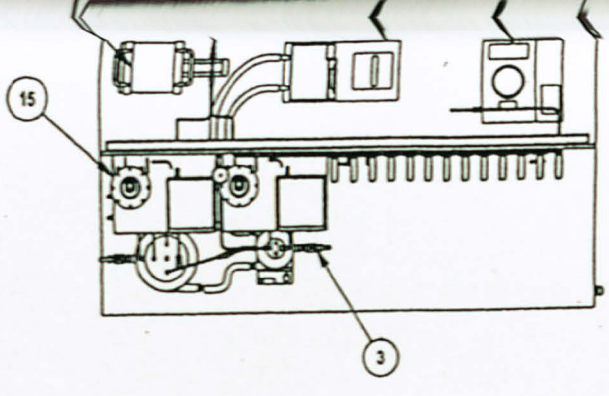
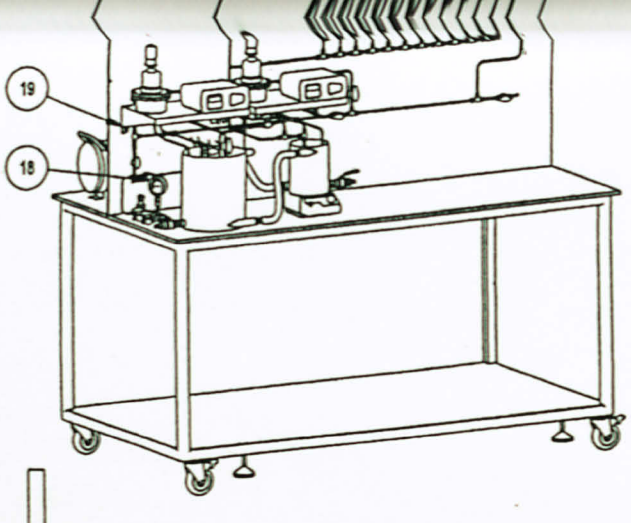
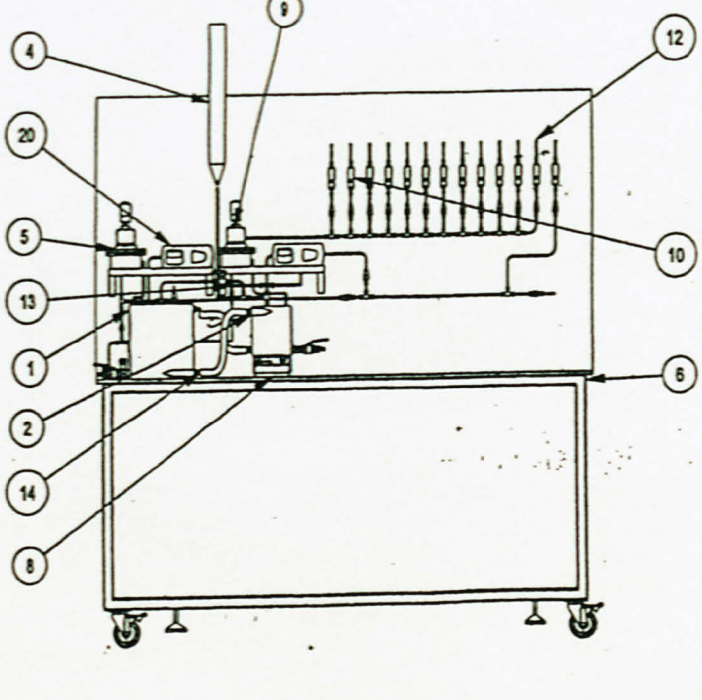
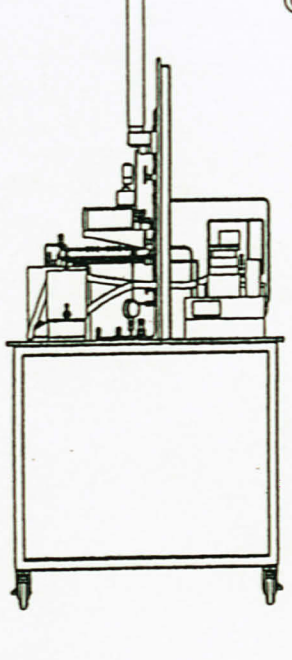
1 L/min
V2
SO2
1 L/min
V3
NO2
1 L/min
V4
O2
2.5 L/min
V5
C1
10 L/min
V6
C2
1 L/min
V7
C3
500 mL/min
V8
nC4
200 mL/min
V9
iC4
200 mL/min
V10
nC5
100 mL/min
V11
iC5
100 mL/min
V12
V13
V14
V15
V16
V17
V18
V19
V20
V21
V22
10 L/min
N2
V23
Vent
1 bar(g)
PI 04
PR1
Gas sampling
V25
V26
PI 05
V27
B6
M1
300°C
TI 01
70 bar(a)
PI 01
B1
3 L
B3
Liquid sampling & drain
300°C
TI 03
TI 02
70 bar(a)
PI 02
P3
B2
300 mL
B4
V28
V29
M1
V30
V31
V32
V33
T1
LEGEND:
Shut off valve
Regulating valve
Pressure regulator
Pressure relief valve
Measuring instrument (transmitter)
Measuring instrument (gauge)
REV
DATE
MODIFICATION
DRAWN
CHECKED
APPROVED
PROJECT TITLE:
UTP PACKAGE 9R-3
CLIENT:
MALAYSIA INTERNATIONAL TRADING CORP. LIAPAQ SDN BHD
Level 11, Tower 1, Petronas Twin Towers, Kuala Lumpur City Centre,
50088 Kuala Lumpur, MALAYSIA.
Tel: 603-20513633 Fax: 603-20512936
DRAWING TITLE:
PROCESS FLOW DIAGRAM FOR
HIGH PRESSURE GAS SOLUBILITY CELL
(MODEL: SOLTEQ® BP 22)
SOLUTION
1, Jalan TPK 3/4, Taman Perindustrian Kinrara,
47100, Puchong, Selangor, Malaysia.
Tel: (03) 8075 8000 Fax: (03) 8075 5784
DRAWN BY: THH
CHECKED BY: CTS
APPROVED BY: MSS
DATE: 10.06.06
SCALE: NTS
SHEET NO: -
PROJECT NO: 264/06/GPS
DRAWING NO: 264-BP22-P01
REV: 3









BILL OF MATERIAL

ITEM	NAME	DESCRIPTION	QTY
1	B1-B4	-	1
2	B2-B5	-	1
3	BALL_VALVE_12	Size: 1/2" Pipe	2
4	CYLINDER		1
5	FLANGE		2
6	FRAME	-	1
7	HEATING-CIRCULATOR	BE-6	1
8	M1	XMD 2 basic 9XAMAD	1
9	MAGNETIC-COUPLING	-	2
10	MASS_FLOW	F-201/CF-211C	13
11	MOTOR-MEDIUM-DUTY		2
12	P01	1/4" SS Tubing	1
13	P02	1/8" SS Tubing	1
14	P03	1/2" Flex pipe	1
15	P1	-	2
16	P3	TSH-971-E	1
17	P4	AD-16	1
18	PRESSURE-GAUGE	Size: 1/4"	1
19	SUPPORT-G	-	2
20	TI_INDICATOR	-	2

NOTE:

1	30-Apr-05	Issued for comments	AZ	THH	DHC

HIGH PRESSURE GAS SOLUBILITY CELL
MODEL: BP22

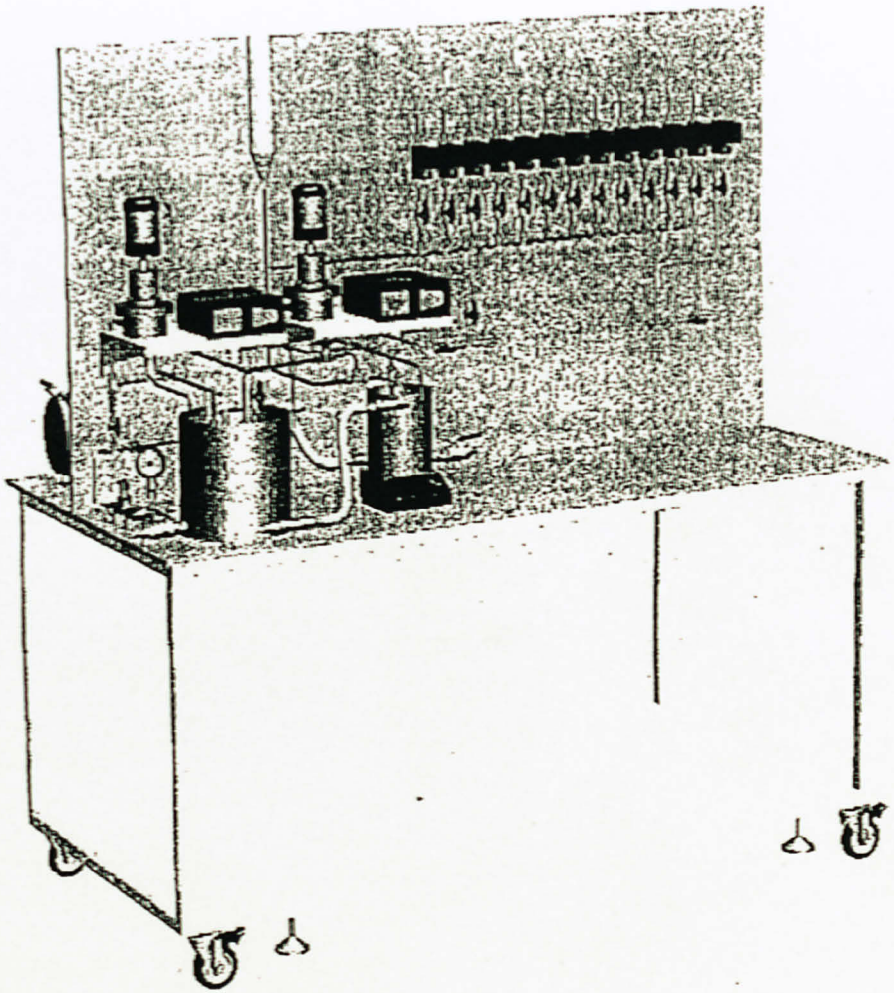
MALAYSIA INTERNATIONAL TRADING CORP (JAPAN) SDN BHD

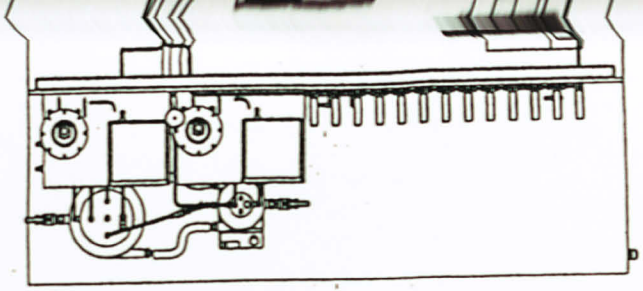
BILL OF MATERIAL - ASSEMBLY DRAWING

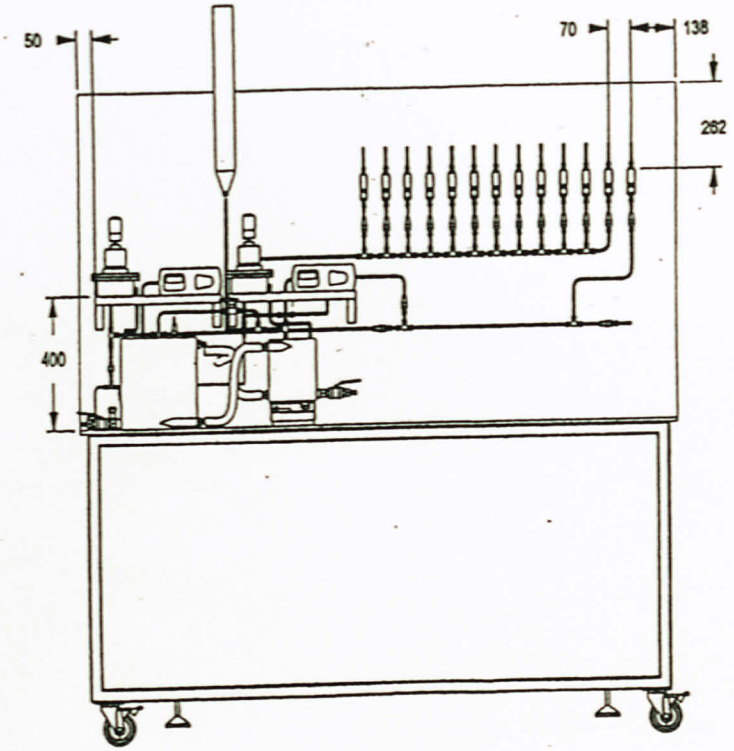
SOLUTION

SOLUTION ENGINEERING SDN BHD

DRAWN BY:	AZ	DATE:	30-Apr-05
DESIGN BY:	THH	SCALE:	0.010
DRAWING BY:	DHC	SHEET NO:	3 of 5
PROJECT NO:	3048BP5	DRAWING NO:	304-BP22-AM
		REV. NO:	1







SCALE 0.060

HIGH PRESSURE GAS SOLUBILITY CELL
MODEL: SP22

MALAYSIA INTERNATIONAL TRADING CORP (JAPAN) SDN BHD

ASSEMBLY DRAWING

SOLUTION ENGINEERING SDN BHD

1 Component Specifications

1. **Mixing vessel (B1)**
   For initial charging and pressurization of gas mixtures
   Volume: 3-L
   Diameter: 154 mm
   Height: 205 mm
   Material: stainless steel

2. **Equilibrium cell (B2)**
   For dissolving gas mixture into liquid
   Volume: 300 mL
   Diameter: 63 mm
   Height: 120 mm
   Material: stainless steel

3. **Heating jacket for mixing vessel (B3)**
   Insulated open tank to immerse the mixing vessel in a circulating bath
   Diameter: 240 mm
   Height: 300 mm
   Material: stainless steel with bottom and side insulation
   Comes with tangential inlet and outlet ports for thermostat connections

4. **Heating jacket for equilibrium cell (B4)**
   Insulated open tank to immerse the equilibrium cell in a circulating bath
   Diameter: 150 mm
   Height: 230 mm
   Material: stainless steel with bottom and side insulation
   Comes with tangential inlet and outlet ports for thermostat connections

5. **Gas booster (P1)**
   Increases the pressure of the gas mixture into the mixing vessel
   Air operated single air head, single acting, single stage booster
   Min. inlet pressure: 3.5 bar
   Max. outlet pressure: 150 bar
   Max. air drive pressure: 10 bar
   Flow capacity:

6. **Vacuum pump (P2)**
   Evacuates the mixing vessel and equilibrium cell
   Turbomolecular vacuum pump with backing diaphragm pump
   Max. vacuum: 1×10^{-4} mbar
   Flow capacity:

7. **Circulation pump (P3)**
   Circulates gas around the equilibrium cell
   Axial flow pump with overhead motor
   Casing volume: 400 mL
   Motor power: 90 W
   Rotation speed: 0 to 1,500 rpm

8. **Liquid feed pump (P5)**
   Introduces liquid into the equilibrium cell at high pressure
   Piston dosing pump
   Adjustable flow range:
   Max. outlet pressure:

9. **Static mixer (M1)**
   Mixes the gases entering the mixing vessel
   Diameter: 1/4"
   No. of elements:

10. **Magnetic stirrer (M2)**
    Mixes the liquid in the equilibrium cell
    Adjustable speed: 100 to 1000 rpm
    Power: 4 W
    Baseplate material: stainless steel
    Stirring bar: 6 mm diameter x 30 mm length

11. **Thermostat heating bath (T1)**
    Provides heat and maintains constant temperature in the heating jackets
    Heating circulator with temperature controller
    Temperature range: 5°C above ambient to 300°C
    Temperature stability: ± 0.01°C
    Heater power: 3 kW
    Pump capacity: 22 to 26 L/min
    Filling volume: 4.5 to 6-L

12. **Liquid degassing unit (B6)**
    Jacketed glass vessel to remove dissolved gas in the liquid
    Volume: 500 mL
    Inner diameter: 70 mm
    Outer diameter: 120 mm
    Material: borosilicate glass
    Comes with feed port, outlet port, vacuum gauge and thermostat connections

2.2 Instrumentation and Control

Tag	Description	Units	Range	Accuracy
Thermal mass flow controllers				
FIC-01	Carbon dioxide, CO_2	NL/min	6.00	± 0.05
FIC-02	Hydrogen sulfide, H_2S	NL/min	1.00	± 0.01
FIC-03	Sulfur dioxide, SO_2	NL/min	1.00	± 0.01
FIC-04	Nitrogen dioxide, NO_2	NL/min	1.00	± 0.01
FIC-05	Oxygen	NL/min	2.50	± 0.02
FIC-06	Methane	NL/min	10.0	± 0.1
FIC-07	Ethane	NL/min	1.00	± 0.01
FIC-08	Propane	NL/min	0.500	± 0.005
FIC-09	n-Butane	NL/min	0.200	± 0.002
FIC-10	Iso-Butane	NL/min	0.200	± 0.002
FIC-11	n-Pentane or nitrogen	NL/min	0.100	± 0.001
FIC-12	Iso-Pentane or nitrogen	NL/min	0.100	± 0.001
Pressure indicators				
PI-01	Mixing vessel	bar(a)	70.0000	± 0.0001
PI-02	Equilibrium cell	bar(a)	70.0000	± 0.0001
Pressure gauges				
PI-03	Vacuum pump	mbar	1×10^{-9}	—
PI-04	GC sampling line	bar(g)	1.00	± 0.025
PI-05	Liquid degassing unit	bar(g)	-1.00	± 0.01
Temperature indicators				
TI-01	Mixing vessel	°C	300.00	± 0.01
TI-02	Liquid in equilibrium cell	°C	300.00	± 0.01
TI-03	Gas in equilibrium cell	°C	300.00	± 0.01

Valves List

Manual hand valves

Tag	Location	Initial position
V1	CO_2 mass flow controller outlet	close
V2	H_2S mass flow controller outlet	close
V3	SO_2 mass flow controller outlet	close
V4	NO_2 mass flow controller outlet	close
V5	Oxygen mass flow controller outlet	close
V6	Methane mass flow controller outlet	close
V7	Ethane mass flow controller outlet	close
V8	Propane mass flow controller outlet	close
V9	n-Butane mass flow controller outlet	close
V10	Iso-Butane mass flow controller outlet	close
V11	n-Pentane mass flow controller outlet	close
V12	iso-Pentane mass flow controller outlet	close
V13	Gas booster P1 inlet	to bypass
V14	Gas booster P1 outlet	to bypass
V15	Gas feed from mixing vessel to equil. cell	close
V16	Liquid feed	close
V17	Liquid sampling or drain for equilibrium cell	close
V18	Vacuum or vent for mixing vessel	close
V19	Vacuum or vent for equilibrium cell	close
V20	Gas sampling for mixing vessel	close
V21	Gas sampling for equilibrium cell	close
V22	Nitrogen mass flow controller outlet	close
V23	Vent	close
V24	Vacuum pump P2 inlet	close
V25	Vacuum for liquid degassing unit B6	close
V26	Feed for liquid degassing unit B6	close
V27	Drain for liquid degassing unit B6	close
V28	Drain for mixing vessel's heating jacket B3	close
V29	Drain for equilibrium cell's heating jacket B4	close
V30	Thermostat inlet to heating jacket B4	close
V31	Thermostat inlet to heating jacket B5	close
V32	Thermostat inlet to liquid degassing unit B6	close
V33	Drain for liquid degassing unit's jacket	close

Pressure regulator and relief valve

Tag	Location	Range
PR1	Regulator for gas sampling to GC	1.0 bar(g)
PRV1	Relief valve at gas booster P1 outlet	65 bar(g)

4 Safety Considerations

1. The unit must be operated under the supervision of an authorized staff who has been properly trained to handle the unit.
2. All operating instructions supplied with the unit must be carefully read and understood before attempting to operate the unit.
3. Only properly trained staff shall be allowed to carry out any servicing. Manufacturer's manual for each component must always be observed.
4. Chemicals which severely affect stainless steel, borosilicate glass and PTFE are not to be used.
5. Always check all safety components such as pressure relief valves to prevent overpressure in the unit.
6. Do not subject to unit to shock, vibration or stress during operation.
7. Leaking connections should be carefully retightened. Replace any gaskets or seals if necessary.
8. Be extremely careful when handling hazardous, flammable or polluting materials.

Appendix B

- ✓ Operating Procedures
- ✓ Experiment Procedures
- ✓ Experiment Layout

3.1 General Operating Procedures

It is important that the user read and fully understand all the instructions and precautions stated in the manufacturer's manual for each components supplied with the unit prior to operation. The following procedures will serve as a quick reference for operating the unit.

1. **Mass flow controllers (FIC-01 to FIC-12)**

   Twelve mass flow controllers are provided to combine different types of gases at the desired composition. To send a set point to the mass flow controllers, the respective indicator has to be switched to manual control by pressing the 'Off' button. Manual control is indicated by a small 'M' on the left. Note that the set point value has only 1 decimal point and represents percent full scale (%FS), not the actual process value. For example, to set the flow rate to 5 L/min (out of full scale 10 L/min), adjust the set point to 50.0% by using the up or down buttons. To turn off the mass flow controllers, press the 'Off' button again to cancel manual control.

2. **Pressure indicators (PI-01 & PI-02)**

   Pressure in both the mixing vessel and equilibrium cell are measured using high accuracy pressure indicators. The indicators can measure and display both gauge and absolute ranges, with a variety of pressure units to choose from. However, the indicators at the control panel can only display the pressure readings in bar(a). To change the range or units, access the 'Settings' menu. The pressure indicators also need to be regularly zeroed to ensure accurate measurements. To zero the instrument, ensure that the indicator is exposed to atmosphere and the current display is showing gauge pressure, then press 'Zero' on the indicator.

3. **Gas booster (P1)**

   The gas booster is air driven, thus do not require any power supply. Turn on the booster by opening the air drive supply valve and regulate the air pressure to control the boosting speed. Ensure that both valves V13 and V14 are switched to the booster and there is gas flow through the booster before turning it on. After pressurizing, switch valve V14 away from the gas booster with V13 facing the opposite direction to isolate pressure in the mixing vessel. During vacuuming or when not in use, always isolate the gas booster from the unit by switching valves V13 and V14 to the bypass line.

4. **Vacuum pump (P2)**

   Before attempting to vacuum the unit, make sure that all valves are in the correct position and the unit is isolated from the atmosphere. Turn on the vacuum pump at the control panel and at the switch located at the bottom of the pump. Press the 'Start/Stop' button on the pump's panel to start and stop the vacuum process.

WARNING: Once the vacuum pump is running, do not open any other valves in the unit to prevent sudden pressure surge into the pump which will damage the turbomolecular pump's blades. In case any valves need to be opened or adjusted during the vacuum process, stop the vacuum pump first and allow the entire unit to vent completely. Then carry out any adjustments before repeating the vacuum process.

The pump will start venting when it is stopped, so close valve V24 before stopping the pump to maintain vacuum in the unit. After stopping the pump, wait for it to vent completely before switching it off.

To view the pump status such as pumping speed and vacuum level, use the right or left button on the pump's panel to scroll through the menu. The pumping speed is located at menu 309 while the vacuum level is located at menu 340. At full capacity, the pumping speed should show 1,500 Hz with a vacuum level below 1 x 10^{-3} mbar. If the full capacity cannot be reached in a short time, there is a leak at the unit.

5. **Circulation pumps (P3)**

Turn on the circulation pump at the control panel and at the speed controller. Adjust the rotational speed by varying the knob on the speed controller. It is advisable to let the pump run at full speed to maximize gas circulation.

6. **Magnetic stirrer (M2)**

Turn on the magnetic stirrer at the control panel and at the stirrer panel. Adjust the stirring speed by varying the knob on the stirrer panel. Rotation of the stirring bar inside the equilibrium cell can be heard when the magnetic stirrer is operating.

7. **Thermostat heating bath (T1)**

Turn on the thermostat heating bath at the control panel and at the thermostat panel. Press the 'T' button to adjust the temperature setpoint. Access the 'Menu' button to change other parameters such as the circulation pump's flow rate at the 'Pump' menu. Press the 'Start/Stop' button to start and stop the bath circulation. Then, open the appropriate valves V30, V31 or V32 to circulate the bath through the heating jacket for mixing vessel B1, equilibrium cell B2 or liquid degassing unit B6 respectively. Remember to close valves V30, V31 and V32 before stopping the thermostat bath to prevent liquid from overflowing from the heating jackets.

2 Purging and Evacuation

The entire unit should be purged with inert gas and fully evacuated before carrying out any experiments. Purging should always be carried out first before evacuation to avoid residue gas or liquid from passing through the vacuum pump during evacuation.

Purging

1. Ensure all valves are in the initial position as listed in Section 2.3.
2. Open valves V15 and V18 to purge both mixing vessel B1 and equilibrium cell B2. Otherwise, open valve V19 to purge only the equilibrium cell B2.
3. Open valve V23 to depressurize the unit before purging, then close valve V23 and open valve V22.
4. Place a beaker beneath valve V17 to drain or collect any residue liquid in the equilibrium cell B2.
5. Open valve V17 and introduce inert gas for purging by setting the flow rate at FIC-13 to around 8—10 NL/min.
6. Allow the inert gas to flow through the unit and out from valve V17 for about 5—10 minutes or until there is no more moisture coming out from the valve.
7. Stop the flow at FIC-13 and close valve V22.
8. Close valves V15, V17, V18 and V19 where applicable.
9. Open valve V23 to vent the unit to atmospheric pressure.

Evacuation

1. Ensure all valves are in the initial position as listed in Section 2.3.
2. Check that the purging steps above have already been carried out.
3. Open valve V24.
4. Open valves V18 and V19 to evacuate both mixing vessel B1 and equilibrium cell B2. Otherwise, open valve V19 to evacuate only the equilibrium cell B2.
5. Switch on vacuum pump P2 and start the vacuum process.

   WARNING: Do not open any other valves at the unit when the vacuum pump is running. If there is any mistake, stop the vacuum pump first and allow the entire unit to vent completely. Rectify the mistake before repeating the vacuum process.

6. Observe the pressure drop in the mixing vessel B1 and/or equilibrium cell B2. Monitor the vacuum reading at the vacuum pump's gauge PI-03 until it is less than 1×10^{-3} mbar.
7. Close valve V24 and stop the vacuum pump. If it needs to be switched off, wait for it to vent completely first.
8. Close valves V18 and V19 where applicable.

3.3 Liquid Degassing

The liquid degassing unit B6 can be used to remove any dissolved gases in the feed liquid through heating and vacuum cycles.

1. Ensure that valves V25, V26, V27 and V33 are closed.
2. Switch on thermostat heating bath T1 and set the desired heating temperature. Start the bath circulation and open valve V32 to allow heating fluid to flow through the degassing unit's jacket.

   CAUTION: Do not set the temperature near or above the boiling point of the feed liquid.

3. Pour in the feed liquid through valve V26.
4. Slightly open valve V25 to prepare for vacuum.
5. Switch on vacuum pump P2 and start the vacuum process. Immediately monitor the vacuum gauge at PI-05 until it reaches the desired level. Quickly close valve V25 and stop the vacuum pump.

   CAUTION: Do not allow the vacuum level to drop to less than –0.9 bar(g) to prevent the liquid from vaporizing.

6. Allow the liquid to stay under vacuum at elevated temperature for about 5 minutes.
7. Release the vacuum by opening valve V26.
8. Repeat steps 4 to 7 above for a few cycles of vacuum.
9. Collect the degassed liquid through valve V27.
10. Close valve V32 and stop the bath circulation at the thermostat heating bath.
11. Switch off vacuum pump P2 and thermostat heating bath T1 if they are not to be used further.

3.4 Gas and Liquid Sample Collection

Gas samples can be analyzed online using the gas chromatograph from both mixing vessel B1 and equilibrium cell B2. Liquid samples can be taken from the equilibrium cell B2 and analyzed offline using the liquid titrator.

Gas samples

1. Ensure that both sampling valves V20 and V21 are initially closed and the pressure regulator PR-1 is fully released (completely turned counterclockwise).
2. To collect a gas sample from mixing vessel B1, open valve V20. To collect a gas sample from equilibrium cell B2, open valve V21.
3. Adjust the pressure regulator PR-1 to achieve exactly 5 psi of pressure in the GC sampling loop as indicated at PI-04. Allow the gas to flow through the sampling loop for a few seconds before taking a sample at the GC.
4. After collecting a sample for GC analysis, close valves V20 and V21. Fully release the pressure regulator PR-1.

Liquid samples

1. Place a liquid sampling bottle beneath valve V17.
2. Slowly open valve V17 to collect a liquid sample from the equilibrium cell B2.
3. Close valve V17 and cap the sampling bottle.
4. Transfer the liquid sample to the titrator for analysis.

EXPERIMENT PROCEDURES

4.1 Start-Up Procedures

1. Ensure all valves are in the initial position as listed in Section 2.3.
2. Decide on which gas to use and open the shut-off valves at all the required gas cylinders. Set the pressure regulators to the desired pressure between 5 to 10 bar(g) and open all the necessary valves at the gas supply lines.
3. Switch on the control panel and check that all instruments and displays are functioning.
4. Perform the purging and evacuation steps for both mixing vessel B1 and equilibrium cell B2 as described in Section 3.2.
5. Prepare about 500 mL of feed liquid and degas it according to Section 3.3.
6. Switch on thermostat heating bath T1 and set the desired heating temperature. Start the bath circulation and open valves V30 and V31 to allow heating fluid to flow through heating jackets B3 and B4.
7. Start-up the gas chromatograph and liquid titrator for operation.

4.2 Preparation of Gas Mixtures

1. Switch bypass valves V13 and V14 towards the gas booster P1.
2. Determine the required flow rate of each gas to achieve a specific composition entering the mixing vessel B1. Enter the flow set points at the respective mass flow controllers.
3. Start introducing gas mixture into the mixing vessel by simultaneously opening the valves at the mass flow controllers for each gas to be used (V1 to V12).
4. Immediately turn on the air drive supply to the gas booster P1.
5. Allow the gas mixture to pressurize the mixing vessel B1 until the desired pressure is reached.
6. Turn off the air drive supply to the gas booster and switch valve V14 towards the bypass line.
7. Immediately turn off all the mass flow controllers and close their respective valves V1 to V12.
8. Allow the temperature in mixing vessel B1 to stabilize before proceeding.
9. Collect and analyze the gas composition in the mixing vessel as described in Section 3.4.

4.3 Solubility Experiment

1. Ensure that the equilibrium cell B2 has been purged and evacuated as described in Section 3.2.
2. Charge equilibrium cell B2 with gas mixtures from mixing vessel B1 by slowly opening valve V15 until the pressure between both mixing vessel and equilibrium cell are equalized. Close valve V15.
3. Allow the temperature in equilibrium cell B2 to stabilize before proceeding.
4. Collect the feed liquid from degassing unit B6 and introduce the desired amount using the liquid feed pump P5 through valve V16.
5. Switch on magnetic stirrer M2 and circulation pump P3.
6. Start the timer and monitor the pressure drop in the equilibrium cell B2 as a result of gas dissolving into the liquid.
7. Stop the timer when the pressure in the equilibrium cell has stabilized.
8. Collect a gas and liquid sample from the equilibrium cell for analysis as described in Section 3.2.
9. Repeat the steps above to carry out the next set of solubility experiment.

4.4 Shut-Down Procedures

1. Switch off magnetic stirrer M2 and circulation pump P3.
2. Reduce the temperature setpoint at the thermostat heating bath T1 to room temperature. Allow the temperature to drop.
3. Perform only the purging steps for both mixing vessel B1 and equilibrium cell B2 as described in Section 3.2.
4. Once the bath temperature has dropped to below 50°C, close valves V30 and V31. Stop the bath circulation and switch it off.
5. Switch off magnetic stirrer M2.
6. Switch off the control panel.
7. Return all valves to the initial position as listed in Section 2.3.

Set of Exp	Solution Mixtures	Mdea (g)	Dea (g)	Pz (g)	H20 (g)	Total Weight (g)	Solution wt%	Op.Temp(°C)	Op.Pressure (bar)
1a	Mdea + H20	3			7	10	30	30,40,50	1,5,10,15
	% in amine mixtures	30%							
1b	Mdea + H20	5			5	10	50	30,40,50	1,5,10,15
	% in amine mixtures	30%							
2a	Mdea + Dea + H20	11.25	3.75		35	50	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	10%						
	100%	75	25						
	Mdea + Dea + H20	9	6		35	50	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%						
	100%	60	40						
2b	Mdea + Dea + H20	18.8	6.3		25.0	50	50	30,40,50	1,5,10,15
	% in amine mixtures	30%	10%						
	100%	75	25						
	Mdea + Dea + H20	15	10		25	50	50	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%						
	100%	60	40						
3a	Mdea + Pz + H20	18.5		43.1	143.6	205.1	30	30,40,50	1,5,10,15
	% in amine mixtures	30%		70%					
	mol fraction of Pz			0.5					
	Mdea + Pz + H20	36.9		86.1	287.1	410.2	30	30,40,50	1,5,10,15
	% in amine mixtures	30%		70%					
	mol fraction of Pz			1					
	Mdea + Pz + H20	55.4		129.2	430.7	615.3	30	30,40,50	1,5,10,15
	% in amine mixtures	30%		70%					
	mol fraction of Pz			1.5					
3b	Mdea + Pz + H20	18.5		43.1	61.5	123.1	50	30,40,50	1,5,10,15
	% in amine mixtures	30%		70%					
	mol fraction of Pz			0.5					
	Mdea + Pz + H20	36.9		86.1	123.1	246.1	50	30,40,50	1,5,10,15
	% in amine mixtures	30%		70%					
	mol fraction of Pz			1					
	Mdea + Pz + H20	55.4		129.2	184.6	369.2	50	30,40,50	1,5,10,15
	% in amine mixtures	30%		70%					
	mol fraction of Pz			1.5					

Set of Exp	Solution Mixtures	Mdea (g)	Dea (g)	Pz (g)	H20 (g)	Total Weight (g)	Solution wt%	Op.Temp(°C)	Op.Pressure (bar)
4a	Mdea + Dea + Pz + H20	21.5	7.2	43.1	167.5	239.3	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	10%	60%					
	100%	30%	10%	60%					
	mol fraction of Pz			0.5					
	Mdea + Dea + Pz + H20	43.1	14.4	86.1	335.0	478.6	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	10%	60%					
	100%	30%	10%	60%					
	mol fraction of Pz			1					
	Mdea + Dea + Pz + H20	64.6	21.5	129.2	502.5	717.8	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	10%	60%					
	100%	30%	10%	60%					
	mol fraction of Pz			1.5					
4b	Mdea + Dea + Pz + H20	25.8	17.2	43.1	201.0	287.1	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%	50%					
	100%	30%	20%	50%					
	mol fraction of Pz			0.5					
	Mdea + Dea + Pz + H20	51.7	34.5	86.1	402.0	574.3	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%	50%					
	100%	30%	20%	50%					
	mol fraction of Pz			1					
	Mdea + Dea + Pz + H20	77.5	51.7	129.2	603.0	861.4	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%	50%					
	100%	30%	20%	50%					
	mol fraction of Pz			1.5					
4ai	Mdea + Dea + Pz + H20	21.5	7.2	43.1	71.8	143.6	50	30,40,50	1,5,10,15

	% in amine mixtures	30%	10%	60%					
	100%	30%	10%	60%					
	mol fraction of Pz			0.5					
	Mdea + Dea + Pz + H20	43.1	14.4	86.1	143.6	287.1	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	10%	60%					
	100%	30%	10%	60%					
	mol fraction of Pz			1					
	Mdea + Dea + Pz + H20	64.6	21.5	129.2	215.4	430.7	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	10%	60%					
	100%	30%	10%	60%					
	mol fraction of Pz			1.5					
4bi	Mdea + Dea + Pz + H20	25.8	17.2	43.1	86.1	172.3	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%	50%					
	100%	30%	20%	50%					
	mol fraction of Pz			0.5					
	Mdea + Dea + Pz + H20	51.7	34.5	86.1	172.3	344.6	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%	50%					
	100%	30%	20%	50%					
	mol fraction of Pz			1					
	Mdea + Dea + Pz + H20	77.5	51.7	129.2	258.4	516.8	30	30,40,50	1,5,10,15
	% in amine mixtures	30%	20%	50%					
	100%	30%	20%	50%					
	mol fraction of Pz			1.5					
	Mdea + Dea + Pz + H20	215.4	86.1	129.2	430.7	861.4	50	30,40,50	1,5,10,15
	% in amine mixtures	50%	20%	30%					
	100%	50%	20%	30%					
	mol fraction of Pz			1.5					

Appendix C

✓ Experimental Results

EXPERIMENTAL DATA

Type of Amine	Methyl Diethanolamine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2 (initial)	mol CO_2/mol amine
1	0.5	1.19	1	0.000793921	0.00000
2	1	1.17	0.98	0.000778043	0.00002
3	1.5	1.16	0.97	0.000770103	0.00002
4	2	1.14	0.95	0.000754225	0.00004
5	2.5	1.13	0.94	0.000746286	0.00005
6	3	1.13	0.94	0.000746286	0.00005
7	3.5	1.13	0.94	0.000746286	0.00005
8	4	1.11	0.92	0.000730407	0.00006
9	4.5	1.1	0.91	0.000722468	0.00007
10	5	1.1	0.91	0.000722468	0.00007
11	5.5	1.08	0.89	0.00070659	0.00009
12	6	1.07	0.88	0.000698651	0.00010
13	6.5	1.07	0.88	0.000698651	0.00010
14	7	1.07	0.88	0.000698651	0.00010
15	7.5	1.06	0.87	0.000690711	0.00010
16	8	1.06	0.87	0.000690711	0.00010
17	8.5	1.05	0.86	0.000682772	0.00011
18	9	1.04	0.85	0.000674833	0.00012
19	9.5	1.04	0.85	0.000674833	0.00012
20	10	1.03	0.84	0.000666894	0.00013
21	10.5	1.03	0.84	0.000666894	0.00013
22	11	1.02	0.83	0.000658955	0.00013
23	11.5	1.02	0.83	0.000658955	0.00013
24	12	1.01	0.82	0.000651015	0.00014
25	12.5	1.01	0.82	0.000651015	0.00014
26	13	1	0.81	0.000643076	0.00015
27	13.5	1	0.81	0.000643076	0.00015
28	14	1.01	0.82	0.000651015	0.00014
29	14.5	0.99	0.8	0.000635137	0.00016
30	15	1	0.81	0.000643076	0.00015
31	15.5	0.99	0.8	0.000635137	0.00016
32	16	0.99	0.8	0.000635137	0.00016
33	16.5	0.99	0.8	0.000635137	0.00016
34	17	1	0.81	0.000643076	0.00015
35	17.5	0.99	0.8	0.000635137	0.00016
36	18	0.99	0.8	0.000635137	0.00016
37	18.5	0.98	0.79	0.000627198	0.00017
38	19	0.98	0.79	0.000627198	0.00017
39	19.5	0.98	0.79	0.000627198	0.00017
40	20	0.98	0.79	0.000627198	0.00017
41	20.5	0.98	0.79	0.000627198	0.00017
42	21	0.98	0.79	0.000627198	0.00017
43	21.5	0.98	0.79	0.000627198	0.00017
44	22	0.98	0.79	0.000627198	0.00017
45	22.5	0.98	0.79	0.000627198	0.00017
46	23	0.98	0.79	0.000627198	0.00017
47	23.5	0.97	0.78	0.000619258	0.00017
48	24	0.97	0.78	0.000619258	0.00017
49	24.5	0.96	0.77	0.000611319	0.00018
50	25	0.96	0.77	0.000611319	0.00018
51	25.5	0.97	0.78	0.000619258	0.00017
52	26	0.95	0.76	0.00060338	0.00019
53	26.5	0.96	0.77	0.000611319	0.00018
54	27	0.96	0.77	0.000611319	0.00018
55	27.5	0.97	0.78	0.000619258	0.00017
56	28	0.97	0.78	0.000619258	0.00017
57	28.5	0.97	0.78	0.000619258	0.00017
58	29	0.96	0.77	0.000611319	0.00018
59	29.5	0.96	0.77	0.000611319	0.00018
60	30	0.96	0.77	0.000611319	0.00018
61	30.5	0.96	0.77	0.000611319	0.00018
62	31	0.96	0.77	0.000611319	0.00018
63	31.5	0.96	0.77	0.000611319	0.00018
64	32	0.96	0.77	0.000611319	0.00018
65	32.5	0.96	0.77	0.000611319	0.00018
66	33	0.96	0.77	0.000611319	0.00018
67	33.5	0.96	0.77	0.000611319	0.00018
68	34	0.95	0.76	0.00060338	0.00019
69	34.5	0.95	0.76	0.00060338	0.00019
70	35	0.95	0.76	0.00060338	0.00019
71	35.5	0.95	0.76	0.00060338	0.00019
72	36	0.95	0.76	0.00060338	0.00019
73	36.5	0.95	0.76	0.00060338	0.00019
74	37	0.95	0.76	0.00060338	0.00019
75	37.5	0.95	0.76	0.00060338	0.00019
76	38	0.95	0.76	0.00060338	0.00019
77	38.5	0.96	0.77	0.000611319	0.00018
78	39	0.96	0.77	0.000611319	0.00018
79	39.5	0.96	0.77	0.000611319	0.00018
80	40	0.95	0.76	0.00060338	0.00019
81	40.5	0.96	0.77	0.000611319	0.00018
82	41	0.96	0.77	0.000611319	0.00018
83	41.5	0.96	0.77	0.000611319	0.00018
84	42	0.95	0.76	0.00060338	0.00019
85	42.5	0.95	0.76	0.00060338	0.00019
86	43	0.95	0.76	0.00060338	0.00019

FYP II FINAL REPORT

87	43.5	0.95	0.76	0.00060338	0.00019
88	44	0.95	0.76	0.00060338	0.00019
89	44.5	0.95	0.76	0.00060338	0.00019
90	45	0.95	0.76	0.00060338	0.00019
91	45.5	0.95	0.76	0.00060338	0.00019
92	46	0.95	0.76	0.00060338	0.00019
93	46.5	0.95	0.76	0.00060338	0.00019
94	47	0.95	0.76	0.00060338	0.00019
95	47.5	0.94	0.75	0.000595441	0.00020
96	48	0.95	0.76	0.00060338	0.00019
97	48.5	0.94	0.75	0.000595441	0.00020
98	49	0.94	0.75	0.000595441	0.00020
99	49.5	0.94	0.75	0.000595441	0.00020
100	50	0.94	0.75	0.000595441	0.00020
101	50.5	0.94	0.75	0.000595441	0.00020
102	51	0.94	0.75	0.000595441	0.00020
103	51.5	0.94	0.75	0.000595441	0.00020
104	52	0.94	0.75	0.000595441	0.00020
105	52.5	0.94	0.75	0.000595441	0.00020
106	53	0.94	0.75	0.000595441	0.00020
107	53.5	0.94	0.75	0.000595441	0.00020
108	54	0.94	0.75	0.000595441	0.00020
109	54.5	0.94	0.75	0.000595441	0.00020
110	55	0.94	0.75	0.000595441	0.00020
111	55.5	0.94	0.75	0.000595441	0.00020
112	56	0.94	0.75	0.000595441	0.00020
113	56.5	0.94	0.75	0.000595441	0.00020
114	57	0.94	0.75	0.000595441	0.00020
115	57.5	0.94	0.75	0.000595441	0.00020
116	58	0.94	0.75	0.000595441	0.00020
117	58.5	0.94	0.75	0.000595441	0.00020
118	59	0.94	0.75	0.000595441	0.00020
119	59.5	0.94	0.75	0.000595441	0.00020
120	60	0.94	0.75	0.000595441	0.00020

Type of Amine	Methyl Diethanolamine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02 (initial)	n C02/ n amine
1	0.5	1.2	1	0.000744762	0.00000
2	1	1.17	0.97	0.000722419	0.00002
3	1.5	1.15	0.95	0.000707524	0.00004
4	2	1.14	0.94	0.000700076	0.00004
5	2.5	1.13	0.93	0.000692629	0.00005
6	3	1.11	0.91	0.000677733	0.00007

FYP II FINAL REPORT

7	3.5	1.09	0.89	0.000662838	0.00008
8	4	1.08	0.88	0.00065539	0.00009
9	4.5	1.08	0.88	0.00065539	0.00009
10	5	1.07	0.87	0.000647943	0.00010
11	5.5	1.06	0.86	0.000640495	0.00010
12	6	1.05	0.85	0.000633048	0.00011
13	6.5	1.04	0.84	0.0006256	0.00012
14	7	1.04	0.84	0.0006256	0.00012
15	7.5	1.04	0.84	0.0006256	0.00012
16	8	1.03	0.83	0.000618152	0.00013
17	8.5	1.02	0.82	0.000610705	0.00013
18	9	1.01	0.81	0.000603257	0.00014
19	9.5	1.02	0.82	0.000610705	0.00013
20	10	1.01	0.81	0.000603257	0.00014
21	10.5	1.01	0.81	0.000603257	0.00014
22	11	1.01	0.81	0.000603257	0.00014
23	11.5	1	0.8	0.00059581	0.00015
24	12	1	0.8	0.00059581	0.00015
25	12.5	1	0.8	0.00059581	0.00015
26	13	0.99	0.79	0.000588362	0.00016
27	13.5	1	0.8	0.00059581	0.00015
28	14	0.99	0.79	0.000588362	0.00016
29	14.5	0.99	0.79	0.000588362	0.00016
30	15	0.99	0.79	0.000588362	0.00016
31	15.5	0.98	0.78	0.000580914	0.00016
32	16	0.99	0.79	0.000588362	0.00016
33	16.5	0.99	0.79	0.000588362	0.00016
34	17	0.99	0.79	0.000588362	0.00016
35	17.5	0.98	0.78	0.000580914	0.00016
36	18	0.99	0.79	0.000588362	0.00016
37	18.5	0.99	0.79	0.000588362	0.00016
38	19	0.98	0.78	0.000580914	0.00016
39	19.5	0.98	0.78	0.000580914	0.00016
40	20	0.98	0.78	0.000580914	0.00016
41	20.5	0.99	0.79	0.000588362	0.00016
42	21	0.98	0.78	0.000580914	0.00016
43	21.5	0.98	0.78	0.000580914	0.00016
44	22	0.97	0.77	0.000573467	0.00017
45	22.5	0.99	0.79	0.000588362	0.00016
46	23	0.98	0.78	0.000580914	0.00016
47	23.5	0.98	0.78	0.000580914	0.00016
48	24	0.97	0.77	0.000573467	0.00017
49	24.5	0.97	0.77	0.000573467	0.00017
50	25	0.98	0.78	0.000580914	0.00016
51	25.5	0.98	0.78	0.000580914	0.00016
52	26	0.98	0.78	0.000580914	0.00016
53	26.5	0.98	0.78	0.000580914	0.00016
54	27	0.98	0.78	0.000580914	0.00016

55	27.5	0.98	0.78	0.000580914	0.00016
56	28	0.98	0.78	0.000580914	0.00016
57	28.5	0.99	0.79	0.000588362	0.00016
58	29	0.99	0.79	0.000588362	0.00016
59	29.5	0.97	0.77	0.000573467	0.00017
60	30	0.98	0.78	0.000580914	0.00016
61	30.5	0.97	0.77	0.000573467	0.00017
62	31	0.98	0.78	0.000580914	0.00016
63	31.5	0.98	0.78	0.000580914	0.00016
64	32	0.98	0.78	0.000580914	0.00016
65	32.5	0.98	0.78	0.000580914	0.00016
66	33	0.98	0.78	0.000580914	0.00016
67	33.5	0.98	0.78	0.000580914	0.00016
68	34	0.98	0.78	0.000580914	0.00016
69	34.5	0.98	0.78	0.000580914	0.00016
70	35	0.98	0.78	0.000580914	0.00016
71	35.5	0.98	0.78	0.000580914	0.00016
72	36	0.98	0.78	0.000580914	0.00016
73	36.5	0.98	0.78	0.000580914	0.00016
74	37	0.98	0.78	0.000580914	0.00016
75	37.5	0.98	0.78	0.000580914	0.00016
76	38	0.98	0.78	0.000580914	0.00016
77	38.5	0.98	0.78	0.000580914	0.00016
78	39	0.98	0.78	0.000580914	0.00016
79	39.5	0.98	0.78	0.000580914	0.00016
80	40	0.98	0.78	0.000580914	0.00016
81	40.5	0.98	0.78	0.000580914	0.00016
82	41	0.98	0.78	0.000580914	0.00016
83	41.5	0.98	0.78	0.000580914	0.00016
84	42	0.98	0.78	0.000580914	0.00016
85	42.5	0.98	0.78	0.000580914	0.00016
86	43	0.98	0.78	0.000580914	0.00016
87	43.5	0.98	0.78	0.000580914	0.00016
88	44	0.98	0.78	0.000580914	0.00016
89	44.5	0.98	0.78	0.000580914	0.00016
90	45	0.98	0.78	0.000580914	0.00016
91	45.5	0.98	0.78	0.000580914	0.00016
92	46	0.98	0.78	0.000580914	0.00016
93	46.5	0.98	0.78	0.000580914	0.00016
94	47	0.98	0.78	0.000580914	0.00016
95	47.5	0.98	0.78	0.000580914	0.00016
96	48	0.98	0.78	0.000580914	0.00016
97	48.5	0.98	0.78	0.000580914	0.00016
98	49	0.98	0.78	0.000580914	0.00016
99	49.5	0.98	0.78	0.000580914	0.00016
100	50	0.98	0.78	0.000580914	0.00016
101	50.5	0.98	0.78	0.000580914	0.00016
102	51	0.98	0.78	0.000580914	0.00016

FYP II FINAL REPORT

103	51.5	0.98	0.78	0.000580914	0.00016
104	52	0.98	0.78	0.000580914	0.00016
105	52.5	0.98	0.78	0.000580914	0.00016
106	53	0.98	0.78	0.000580914	0.00016
107	53.5	0.98	0.78	0.000580914	0.00016
108	54	0.98	0.78	0.000580914	0.00016
109	54.5	0.98	0.78	0.000580914	0.00016
110	55	0.98	0.78	0.000580914	0.00016
111	55.5	0.98	0.78	0.000580914	0.00016
112	56	0.98	0.78	0.000580914	0.00016
113	56.5	0.98	0.78	0.000580914	0.00016
114	57	0.98	0.78	0.000580914	0.00016
115	57.5	0.98	0.78	0.000580914	0.00016
116	58	0.98	0.78	0.000580914	0.00016
117	58.5	0.98	0.78	0.000580914	0.00016
118	59	0.98	0.78	0.000580914	0.00016
119	59.5	0.98	0.78	0.000580914	0.00016
120	60	0.98	0.78	0.000580914	0.00016

Type of Amine	Methyl Diethanolamine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02 (initial)	n C02/ n amine
1	0.5	1.25	1	0.000793921	0.00000
2	1	1.22	0.97	0.000770103	0.00002
3	1.5	1.19	0.94	0.000746286	0.00005
4	2	1.17	0.92	0.000730407	0.00006
5	2.5	1.16	0.91	0.000722468	0.00007
6	3	1.13	0.88	0.000698651	0.00010
7	3.5	1.11	0.86	0.000682772	0.00011
8	4	1.09	0.84	0.000666894	0.00013
9	4.5	1.09	0.84	0.000666894	0.00013
10	5	1.08	0.83	0.000658955	0.00013
11	5.5	1.06	0.81	0.000643076	0.00015
12	6	1.05	0.8	0.000635137	0.00016
13	6.5	1.04	0.79	0.000627198	0.00017
14	7	1.02	0.77	0.000611319	0.00018
15	7.5	1.01	0.76	0.00060338	0.00019
16	8	1	0.75	0.000595441	0.00020
17	8.5	0.99	0.74	0.000587502	0.00021
18	9	0.98	0.73	0.000579562	0.00021
19	9.5	0.97	0.72	0.000571623	0.00022
20	10	0.96	0.71	0.000563684	0.00023
21	10.5	0.95	0.7	0.000555745	0.00024

FYP II FINAL REPORT

22	11	0.95	0.7	0.000555745	0.00024
23	11.5	0.94	0.69	0.000547806	0.00025
24	12	0.94	0.69	0.000547806	0.00025
25	12.5	0.93	0.68	0.000539866	0.00025
26	13	0.92	0.67	0.000531927	0.00026
27	13.5	0.92	0.67	0.000531927	0.00026
28	14	0.91	0.66	0.000523988	0.00027
29	14.5	0.91	0.66	0.000523988	0.00027
30	15	0.9	0.65	0.000516049	0.00028
31	15.5	0.9	0.65	0.000516049	0.00028
32	16	0.9	0.65	0.000516049	0.00028
33	16.5	0.89	0.64	0.00050811	0.00029
34	17	0.89	0.64	0.00050811	0.00029
35	17.5	0.89	0.64	0.00050811	0.00029
36	18	0.88	0.63	0.00050017	0.00029
37	18.5	0.88	0.63	0.00050017	0.00029
38	19	0.87	0.62	0.000492231	0.00030
39	19.5	0.87	0.62	0.000492231	0.00030
40	20	0.87	0.62	0.000492231	0.00030
41	20.5	0.87	0.62	0.000492231	0.00030
42	21	0.86	0.61	0.000484292	0.00031
43	21.5	0.87	0.62	0.000492231	0.00030
44	22	0.86	0.61	0.000484292	0.00031
45	22.5	0.86	0.61	0.000484292	0.00031
46	23	0.85	0.6	0.000476353	0.00032
47	23.5	0.86	0.61	0.000484292	0.00031
48	24	0.85	0.6	0.000476353	0.00032
49	24.5	0.85	0.6	0.000476353	0.00032
50	25	0.85	0.6	0.000476353	0.00032
51	25.5	0.85	0.6	0.000476353	0.00032
52	26	0.84	0.59	0.000468413	0.00033
53	26.5	0.85	0.6	0.000476353	0.00032
54	27	0.85	0.6	0.000476353	0.00032
55	27.5	0.85	0.6	0.000476353	0.00032
56	28	0.85	0.6	0.000476353	0.00032
57	28.5	0.84	0.59	0.000468413	0.00033
58	29	0.85	0.6	0.000476353	0.00032
59	29.5	0.84	0.59	0.000468413	0.00033
60	30	0.84	0.59	0.000468413	0.00033
61	30.5	0.85	0.6	0.000476353	0.00032
62	31	0.85	0.6	0.000476353	0.00032
63	31.5	0.85	0.6	0.000476353	0.00032
64	32	0.84	0.59	0.000468413	0.00033
65	32.5	0.84	0.59	0.000468413	0.00033
66	33	0.84	0.59	0.000468413	0.00033
67	33.5	0.85	0.6	0.000476353	0.00032
68	34	0.84	0.59	0.000468413	0.00033
69	34.5	0.84	0.59	0.000468413	0.00033
70	35	0.84	0.59	0.000468413	0.00033
71	35.5	0.84	0.59	0.000468413	0.00033
72	36	0.84	0.59	0.000468413	0.00033
73	36.5	0.84	0.59	0.000468413	0.00033
74	37	0.84	0.59	0.000468413	0.00033
75	37.5	0.84	0.59	0.000468413	0.00033
76	38	0.84	0.59	0.000468413	0.00033
77	38.5	0.84	0.59	0.000468413	0.00033
78	39	0.84	0.59	0.000468413	0.00033
79	39.5	0.84	0.59	0.000468413	0.00033
80	40	0.84	0.59	0.000468413	0.00033
81	40.5	0.84	0.59	0.000468413	0.00033
82	41	0.84	0.59	0.000468413	0.00033
83	41.5	0.84	0.59	0.000468413	0.00033
84	42	0.84	0.59	0.000468413	0.00033
85	42.5	0.84	0.59	0.000468413	0.00033
86	43	0.84	0.59	0.000468413	0.00033
87	43.5	0.84	0.59	0.000468413	0.00033
88	44	0.84	0.59	0.000468413	0.00033
89	44.5	0.84	0.59	0.000468413	0.00033
90	45	0.84	0.59	0.000468413	0.00033
91	45.5	0.84	0.59	0.000468413	0.00033
92	46	0.84	0.59	0.000468413	0.00033
93	46.5	0.84	0.59	0.000468413	0.00033
94	47	0.84	0.59	0.000468413	0.00033
95	47.5	0.84	0.59	0.000468413	0.00033
96	48	0.84	0.59	0.000468413	0.00033
97	48.5	0.84	0.59	0.000468413	0.00033
98	49	0.84	0.59	0.000468413	0.00033
99	49.5	0.84	0.59	0.000468413	0.00033
100	50	0.84	0.59	0.000468413	0.00033
101	50.5	0.84	0.59	0.000468413	0.00033
102	51	0.84	0.59	0.000468413	0.00033
103	51.5	0.84	0.59	0.000468413	0.00033
104	52	0.84	0.59	0.000468413	0.00033
105	52.5	0.84	0.59	0.000468413	0.00033
106	53	0.84	0.59	0.000468413	0.00033
107	53.5	0.84	0.59	0.000468413	0.00033
108	54	0.84	0.59	0.000468413	0.00033
109	54.5	0.84	0.59	0.000468413	0.00033
110	55	0.84	0.59	0.000468413	0.00033
111	55.5	0.84	0.59	0.000468413	0.00033
112	56	0.84	0.59	0.000468413	0.00033
113	56.5	0.84	0.59	0.000468413	0.00033
114	57	0.84	0.59	0.000468413	0.00033
115	57.5	0.84	0.59	0.000468413	0.00033
116	58	0.84	0.59	0.000468413	0.00033
117	58.5	0.84	0.59	0.000468413	0.00033

118	59	0.84	0.59	0.000468413	0.00033
119	59.5	0.84	0.59	0.000468413	0.00033
120	60	0.84	0.59	0.000468413	0.00033

Type of Amine: Methyl Diethanolamine
Total Solution Concentration (wt%): 50
Volume of solution (m^3): 0.0002
Temperature (°C): 50
Pressure (bar): 1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02 (initial)	n C02/ n amine
1	0.5	1.04	1	0.000744762	0.00000
2	1	1.15	0.99	0.000737314	0.00001
3	1.5	1.21	0.98	0.000729867	0.00001
4	2	1.16	0.97	0.000722419	0.00002
5	2.5	1.15	0.97	0.000722419	0.00002
6	3	1.12	0.96	0.000714971	0.00003
7	3.5	1.09	0.93	0.000692629	0.00005
8	4	1.07	0.91	0.000677733	0.00007
9	4.5	1.06	0.9	0.000670286	0.00007
10	5	1.05	0.89	0.000662838	0.00008
11	5.5	1.02	0.86	0.000640495	0.00010
12	6	1.01	0.85	0.000633048	0.00011
13	6.5	1	0.84	0.0006256	0.00012
14	7	0.98	0.82	0.000610705	0.00013
15	7.5	0.98	0.82	0.000610705	0.00013
16	8	0.96	0.8	0.00059581	0.00015
17	8.5	0.95	0.79	0.000588362	0.00016
18	9	0.95	0.79	0.000588362	0.00016
19	9.5	0.95	0.79	0.000588362	0.00016
20	10	0.93	0.77	0.000573467	0.00017
21	10.5	0.93	0.77	0.000573467	0.00017
22	11	0.93	0.77	0.000573467	0.00017
23	11.5	0.92	0.76	0.000566019	0.00018
24	12	0.91	0.75	0.000558571	0.00019
25	12.5	0.91	0.75	0.000558571	0.00019
26	13	0.9	0.74	0.000551124	0.00019
27	13.5	0.91	0.75	0.000558571	0.00019
28	14	0.9	0.74	0.000551124	0.00019
29	14.5	0.89	0.73	0.000543676	0.00020
30	15	0.89	0.73	0.000543676	0.00020
31	15.5	0.89	0.73	0.000543676	0.00020
32	16	0.89	0.73	0.000543676	0.00020
33	16.5	0.87	0.71	0.000528781	0.00022
34	17	0.88	0.72	0.000536229	0.00021
35	17.5	0.88	0.72	0.000536229	0.00021
36	18	0.87	0.71	0.000528781	0.00022

FYP II FINAL REPORT

37	18.5	0.87	0.71	0.000528781	0.00022
38	19	0.87	0.71	0.000528781	0.00022
39	19.5	0.87	0.71	0.000528781	0.00022
40	20	0.87	0.71	0.000528781	0.00022
41	20.5	0.87	0.71	0.000528781	0.00022
42	21	0.86	0.7	0.000521333	0.00022
43	21.5	0.86	0.7	0.000521333	0.00022
44	22	0.86	0.7	0.000521333	0.00022
45	22.5	0.86	0.7	0.000521333	0.00022
46	23	0.86	0.7	0.000521333	0.00022
47	23.5	0.85	0.69	0.000513886	0.00023
48	24	0.85	0.69	0.000513886	0.00023
49	24.5	0.86	0.7	0.000521333	0.00022
50	25	0.86	0.7	0.000521333	0.00022
51	25.5	0.85	0.69	0.000513886	0.00023
52	26	0.85	0.69	0.000513886	0.00023
53	26.5	0.86	0.7	0.000521333	0.00022
54	27	0.85	0.69	0.000513886	0.00023
55	27.5	0.85	0.69	0.000513886	0.00023
56	28	0.86	0.7	0.000521333	0.00022
57	28.5	0.86	0.7	0.000521333	0.00022
58	29	0.85	0.69	0.000513886	0.00023
59	29.5	0.85	0.69	0.000513886	0.00023
60	30	0.85	0.69	0.000513886	0.00023
61	30.5	0.85	0.69	0.000513886	0.00023
62	31	0.85	0.69	0.000513886	0.00023
63	31.5	0.85	0.69	0.000513886	0.00023
64	32	0.84	0.68	0.000506438	0.00024
65	32.5	0.85	0.69	0.000513886	0.00023
66	33	0.85	0.69	0.000513886	0.00023
67	33.5	0.84	0.68	0.000506438	0.00024
68	34	0.85	0.69	0.000513886	0.00023
69	34.5	0.84	0.68	0.000506438	0.00024
70	35	0.84	0.68	0.000506438	0.00024
71	35.5	0.85	0.69	0.000513886	0.00023
72	36	0.85	0.69	0.000513886	0.00023
73	36.5	0.85	0.69	0.000513886	0.00023
74	37	0.85	0.69	0.000513886	0.00023
75	37.5	0.85	0.69	0.000513886	0.00023
76	38	0.85	0.69	0.000513886	0.00023
77	38.5	0.85	0.69	0.000513886	0.00023
78	39	0.85	0.69	0.000513886	0.00023
79	39.5	0.85	0.69	0.000513886	0.00023
80	40	0.85	0.69	0.000513886	0.00023
81	40.5	0.85	0.69	0.000513886	0.00023
82	41	0.85	0.69	0.000513886	0.00023
83	41.5	0.85	0.69	0.000513886	0.00023
84	42	0.85	0.69	0.000513886	0.00023

85	42.5	0.85	0.69	0.000513886	0.00023
86	43	0.85	0.69	0.000513886	0.00023
87	43.5	0.85	0.69	0.000513886	0.00023
88	44	0.85	0.69	0.000513886	0.00023
89	44.5	0.85	0.69	0.000513886	0.00023
90	45	0.85	0.69	0.000513886	0.00023
91	45.5	0.85	0.69	0.000513886	0.00023
92	46	0.85	0.69	0.000513886	0.00023
93	46.5	0.85	0.69	0.000513886	0.00023
94	47	0.85	0.69	0.000513886	0.00023
95	47.5	0.85	0.69	0.000513886	0.00023
96	48	0.85	0.69	0.000513886	0.00023
97	48.5	0.85	0.69	0.000513886	0.00023
98	49	0.85	0.69	0.000513886	0.00023
99	49.5	0.85	0.69	0.000513886	0.00023
100	50	0.85	0.69	0.000513886	0.00023
101	50.5	0.85	0.69	0.000513886	0.00023
102	51	0.85	0.69	0.000513886	0.00023
103	51.5	0.85	0.69	0.000513886	0.00023
104	52	0.85	0.69	0.000513886	0.00023
105	52.5	0.85	0.69	0.000513886	0.00023
106	53	0.85	0.69	0.000513886	0.00023
107	53.5	0.85	0.69	0.000513886	0.00023
108	54	0.85	0.69	0.000513886	0.00023
109	54.5	0.85	0.69	0.000513886	0.00023
110	55	0.85	0.69	0.000513886	0.00023
111	55.5	0.85	0.69	0.000513886	0.00023
112	56	0.85	0.69	0.000513886	0.00023
113	56.5	0.85	0.69	0.000513886	0.00023
114	57	0.85	0.69	0.000513886	0.00023
115	57.5	0.85	0.69	0.000513886	0.00023
116	58	0.85	0.69	0.000513886	0.00023
117	58.5	0.85	0.69	0.000513886	0.00023
118	59	0.85	0.69	0.000513886	0.00023
119	59.5	0.85	0.69	0.000513886	0.00023
120	60	0.85	0.69	0.000513886	0.00023

Type of Amine	Methyl Diethanolamine / Diethanolamine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	mol CO_2 (initial)	mol C02/mol amine
1	0.5	1.15	1	0.000793921	0.00000
2	1	1.09	0.94	0.000746286	0.00005
3	1.5	1.07	0.92	0.000730407	0.00006

FYP II FINAL REPORT

4	2	1.02	0.87	0.000690711	0.00010
5	2.5	0.94	0.79	0.000627198	0.00017
6	3	0.91	0.76	0.00060338	0.00019
7	3.5	0.87	0.72	0.000571623	0.00022
8	4	0.84	0.69	0.000547806	0.00025
9	4.5	0.82	0.67	0.000531927	0.00026
10	5	0.79	0.64	0.00050811	0.00029
11	5.5	0.77	0.62	0.000492231	0.00030
12	6	0.75	0.6	0.000476353	0.00032
13	6.5	0.73	0.58	0.000460474	0.00033
14	7	0.71	0.56	0.000444596	0.00035
15	7.5	0.69	0.54	0.000428717	0.00037
16	8	0.68	0.53	0.000420778	0.00037
17	8.5	0.67	0.52	0.000412839	0.00038
18	9	0.66	0.51	0.0004049	0.00039
19	9.5	0.65	0.5	0.000396961	0.00040
20	10	0.64	0.49	0.000389021	0.00040
21	10.5	0.63	0.48	0.000381082	0.00041
22	11	0.62	0.47	0.000373143	0.00042
23	11.5	0.62	0.47	0.000373143	0.00042
24	12	0.62	0.47	0.000373143	0.00042
25	12.5	0.61	0.46	0.000365204	0.00043
26	13	0.6	0.45	0.000357264	0.00044
27	13.5	0.6	0.45	0.000357264	0.00044
28	14	0.6	0.45	0.000357264	0.00044
29	14.5	0.59	0.44	0.000349325	0.00044
30	15	0.59	0.44	0.000349325	0.00044
31	15.5	0.6	0.45	0.000357264	0.00044
32	16	0.59	0.44	0.000349325	0.00044
33	16.5	0.59	0.44	0.000349325	0.00044
34	17	0.59	0.44	0.000349325	0.00044
35	17.5	0.59	0.44	0.000349325	0.00044
36	18	0.58	0.43	0.000341386	0.00045
37	18.5	0.59	0.44	0.000349325	0.00044
38	19	0.58	0.43	0.000341386	0.00045
39	19.5	0.59	0.44	0.000349325	0.00044
40	20	0.58	0.43	0.000341386	0.00045
41	20.5	0.58	0.43	0.000341386	0.00045
42	21	0.58	0.43	0.000341386	0.00045
43	21.5	0.58	0.43	0.000341386	0.00045
44	22	0.58	0.43	0.000341386	0.00045
45	22.5	0.58	0.43	0.000341386	0.00045
46	23	0.58	0.43	0.000341386	0.00045
47	23.5	0.58	0.43	0.000341386	0.00045
48	24	0.58	0.43	0.000341386	0.00045
49	24.5	0.58	0.43	0.000341386	0.00045
50	25	0.57	0.42	0.000333447	0.00046
51	25.5	0.58	0.43	0.000341386	0.00045

52	26	0.57	0.44	0.000349325	0.00044
53	26.5	0.57	0.43	0.000341386	0.00045
54	27	0.57	0.43	0.000341386	0.00045
55	27.5	0.57	0.43	0.000341386	0.00045
56	28	0.57	0.43	0.000341386	0.00045
57	28.5	0.57	0.43	0.000341386	0.00045
58	29	0.57	0.43	0.000341386	0.00045
59	29.5	0.57	0.43	0.000341386	0.00045
60	30	0.57	0.43	0.000341386	0.00045
61	30.5	0.57	0.43	0.000341386	0.00045
62	31	0.57	0.43	0.000341386	0.00045
63	31.5	0.57	0.43	0.000341386	0.00045
64	32	0.57	0.43	0.000341386	0.00045
65	32.5	0.57	0.43	0.000341386	0.00045
66	33	0.57	0.43	0.000341386	0.00045
67	33.5	0.57	0.43	0.000341386	0.00045
68	34	0.57	0.44	0.000349325	0.00044
69	34.5	0.57	0.44	0.000349325	0.00044
70	35	0.57	0.44	0.000349325	0.00044
71	35.5	0.57	0.44	0.000349325	0.00044
72	36	0.57	0.44	0.000349325	0.00044
73	36.5	0.57	0.44	0.000349325	0.00044
74	37	0.57	0.44	0.000349325	0.00044
75	37.5	0.57	0.44	0.000349325	0.00044
76	38	0.57	0.44	0.000349325	0.00044
77	38.5	0.57	0.44	0.000349325	0.00044
78	39	0.57	0.44	0.000349325	0.00044
79	39.5	0.57	0.44	0.000349325	0.00044
80	40	0.57	0.44	0.000349325	0.00044
81	40.5	0.57	0.44	0.000349325	0.00044
82	41	0.57	0.44	0.000349325	0.00044
83	41.5	0.57	0.44	0.000349325	0.00044
84	42	0.57	0.44	0.000349325	0.00044
85	42.5	0.57	0.44	0.000349325	0.00044
86	43	0.57	0.44	0.000349325	0.00044
87	43.5	0.57	0.44	0.000349325	0.00044
88	44	0.57	0.44	0.000349325	0.00044
89	44.5	0.57	0.44	0.000349325	0.00044
90	45	0.57	0.44	0.000349325	0.00044
91	45.5	0.57	0.43	0.000341386	0.00045
92	46	0.57	0.43	0.000341386	0.00045
93	46.5	0.57	0.43	0.000341386	0.00045
94	47	0.57	0.43	0.000341386	0.00045
95	47.5	0.57	0.44	0.000349325	0.00044
96	48	0.57	0.44	0.000349325	0.00044
97	48.5	0.57	0.44	0.000349325	0.00044
98	49	0.57	0.44	0.000349325	0.00044
99	49.5	0.57	0.44	0.000349325	0.00044

FYP II FINAL REPORT

100	50	0.57	0.44	0.000349325	0.00044
101	50.5	0.57	0.44	0.000349325	0.00044
102	51	0.57	0.44	0.000349325	0.00044
103	51.5	0.57	0.44	0.000349325	0.00044
104	52	0.57	0.44	0.000349325	0.00044
105	52.5	0.57	0.44	0.000349325	0.00044
106	53	0.57	0.43	0.000341386	0.00045
107	53.5	0.57	0.43	0.000341386	0.00045
108	54	0.57	0.43	0.000341386	0.00045
109	54.5	0.57	0.43	0.000341386	0.00045
110	55	0.57	0.43	0.000341386	0.00045
111	55.5	0.57	0.43	0.000341386	0.00045
112	56	0.57	0.43	0.000341386	0.00045
113	56.5	0.57	0.43	0.000341386	0.00045
114	57	0.57	0.43	0.000341386	0.00045
115	57.5	0.57	0.43	0.000341386	0.00045
116	58	0.57	0.43	0.000341386	0.00045
117	58.5	0.57	0.43	0.000341386	0.00045
118	59	0.57	0.43	0.000341386	0.00045
119	59.5	0.57	0.43	0.000341386	0.00045
120	60	0.57	0.43	0.000341386	0.00045

Type of Amine	Methyl Diethanolamine / Diethanolamine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02 (initial)	n CO2/ n amine
1	0.5	1	1	0.000744762	0.00000
2	1	0.98	0.98	0.000729867	0.00001
3	1.5	0.93	0.93	0.000692629	0.00005
4	2	0.88	0.88	0.00065539	0.00009
5	2.5	0.83	0.83	0.000618152	0.00013
6	3	0.79	0.79	0.000588362	0.00016
7	3.5	0.75	0.75	0.000558571	0.00019
8	4	0.75	0.75	0.000558571	0.00019
9	4.5	0.74	0.74	0.000551124	0.00019
10	5	0.7	0.7	0.000521333	0.00022
11	5.5	0.69	0.69.	0.000513886	0.00023
12	6	0.67	0.67	0.00049899	0.00025
13	6.5	0.67	0.67	0.00049899	0.00025
14	7	0.65	0.65	0.000484095	0.00026
15	7.5	0.64	0.64	0.000476648	0.00027
16	8	0.64	0.64	0.000476648	0.00027
17	8.5	0.63	0.63	0.0004692	0.00028
18	9	0.63	0.63	0.0004692	0.00028

FYP II FINAL REPORT

19	9.5	0.62	0.62	0.000461752	0.00028
20	10	0.62	0.62	0.000461752	0.00028
21	10.5	0.62	0.62	0.000461752	0.00028
22	11	0.62	0.62	0.000461752	0.00028
23	11.5	0.62	0.62	0.000461752	0.00028
24	12	0.62	0.62	0.000461752	0.00028
25	12.5	0.62	0.62	0.000461752	0.00028
26	13	0.62	0.62	0.000461752	0.00028
27	13.5	0.61	0.61	0.000454305	0.00029
28	14	0.61	0.61	0.000454305	0.00029
29	14.5	0.61	0.61	0.000454305	0.00029
30	15	0.61	0.61	0.000454305	0.00029
31	15.5	0.61	0.61	0.000454305	0.00029
32	16	0.62	0.62	0.000461752	0.00028
33	16.5	0.62	0.62	0.000461752	0.00028
34	17	0.6	0.6	0.000446857	0.00030
35	17.5	0.61	0.61	0.000454305	0.00029
36	18	0.61	0.61	0.000454305	0.00029
37	18.5	0.61	0.61	0.000454305	0.00029
38	19	0.61	0.61	0.000454305	0.00029
39	19.5	0.61	0.61	0.000454305	0.00029
40	20	0.61	0.61	0.000454305	0.00029
41	20.5	0.61	0.61	0.000454305	0.00029
42	21	0.61	0.61	0.000454305	0.00029
43	21.5	0.6	0.6	0.000446857	0.00030
44	22	0.61	0.61	0.000454305	0.00029
45	22.5	0.61	0.61	0.000454305	0.00029
46	23	0.6	0.6	0.000446857	0.00030
47	23.5	0.6	0.6	0.000446857	0.00030
48	24	0.6	0.6	0.000446857	0.00030
49	24.5	0.61	0.61	0.000454305	0.00029
50	25	0.61	0.61	0.000454305	0.00029
51	25.5	0.61	0.61	0.000454305	0.00029
52	26	0.61	0.61	0.000454305	0.00029
53	26.5	0.61	0.61	0.000454305	0.00029
54	27	0.61	0.61	0.000454305	0.00029
55	27.5	0.61	0.61	0.000454305	0.00029
56	28	0.6	0.6	0.000446857	0.00030
57	28.5	0.61	0.61	0.000454305	0.00029
58	29	0.61	0.61	0.000454305	0.00029
59	29.5	0.61	0.61	0.000454305	0.00029
60	30	0.61	0.61	0.000454305	0.00029
61	30.5	0.6	0.6	0.000446857	0.00030
62	31	0.6	0.6	0.000446857	0.00030
63	31.5	0.6	0.6	0.000446857	0.00030
64	32	0.6	0.61	0.000454305	0.00029
65	32.5	0.6	0.61	0.000454305	0.00029
66	33	0.6	0.61	0.000454305	0.00029
67	33.5	0.6	0.61	0.000454305	0.00029
68	34	0.6	0.61	0.000454305	0.00029
69	34.5	0.6	0.61	0.000454305	0.00029
70	35	0.6	0.61	0.000454305	0.00029
71	35.5	0.6	0.6	0.000446857	0.00030
72	36	0.6	0.6	0.000446857	0.00030
73	36.5	0.6	0.61	0.000454305	0.00029
74	37	0.6	0.61	0.000454305	0.00029
75	37.5	0.6	0.6	0.000446857	0.00030
76	38	0.6	0.6	0.000446857	0.00030
77	38.5	0.6	0.61	0.000454305	0.00029
78	39	0.6	0.6	0.000446857	0.00030
79	39.5	0.6	0.6	0.000446857	0.00030
80	40	0.6	0.6	0.000446857	0.00030
81	40.5	0.6	0.6	0.000446857	0.00030
82	41	0.6	0.6	0.000446857	0.00030
83	41.5	0.6	0.6	0.000446857	0.00030
84	42	0.6	0.6	0.000446857	0.00030
85	42.5	0.6	0.6	0.000446857	0.00030
86	43	0.6	0.6	0.000446857	0.00030
87	43.5	0.6	0.6	0.000446857	0.00030
88	44	0.6	0.6	0.000446857	0.00030
89	44.5	0.6	0.6	0.000446857	0.00030
90	45	0.6	0.6	0.000446857	0.00030
91	45.5	0.6	0.6	0.000446857	0.00030
92	46	0.6	0.6	0.000446857	0.00030
93	46.5	0.6	0.6	0.000446857	0.00030
94	47	0.6	0.6	0.000446857	0.00030
95	47.5	0.6	0.6	0.000446857	0.00030
96	48	0.6	0.6	0.000446857	0.00030
97	48.5	0.6	0.6	0.000446857	0.00030
98	49	0.6	0.6	0.000446857	0.00030
99	49.5	0.6	0.6	0.000446857	0.00030
100	50	0.6	0.6	0.000446857	0.00030
101	50.5	0.6	0.6	0.000446857	0.00030
102	51	0.6	0.6	0.000446857	0.00030
103	51.5	0.6	0.6	0.000446857	0.00030
104	52	0.6	0.6	0.000446857	0.00030
105	52.5	0.6	0.6	0.000446857	0.00030
106	53	0.6	0.6	0.000446857	0.00030
107	53.5	0.6	0.6	0.000446857	0.00030
108	54	0.6	0.6	0.000446857	0.00030
109	54.5	0.6	0.6	0.000446857	0.00030
110	55	0.6	0.6	0.000446857	0.00030
111	55.5	0.6	0.6	0.000446857	0.00030
112	56	0.6	0.6	0.000446857	0.00030
113	56.5	0.6	0.6	0.000446857	0.00030
114	57	0.6	0.6	0.000446857	0.00030

115	57.5	0.6	0.6	0.000446857	0.00030
116	58	0.6	0.6	0.000446857	0.00030
117	58.5	0.6	0.6	0.000446857	0.00030
118	59	0.6	0.6	0.000446857	0.00030
119	59.5	0.6	0.6	0.000446857	0.00030
120	60	0.6	0.6	0.000446857	0.00030

Type of Amine	Methyl Diethanolamine / Diethanolamine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02 (initial)	n CO2/ n amine
1	0.5	1.12	1	0.000793921	0.00000
2	1	0.99	0.87	0.000690711	0.00010
3	1.5	0.8	0.68	0.000539866	0.00025
4	2	0.76	0.64	0.00050811	0.00029
5	2.5	0.72	0.6	0.000476353	0.00032
6	3	0.69	0.57	0.000452535	0.00034
7	3.5	0.66	0.54	0.000428717	0.00037
8	4	0.64	0.52	0.000412839	0.00038
9	4.5	0.62	0.5	0.000396961	0.00040
10	5	0.61	0.49	0.000389021	0.00040
11	5.5	0.6	0.48	0.000381082	0.00041
12	6	0.59	0.47	0.000373143	0.00042
13	6.5	0.59	0.47	0.000373143	0.00042
14	7	0.59	0.47	0.000373143	0.00042
15	7.5	0.58	0.46	0.000365204	0.00043
16	8	0.58	0.46	0.000365204	0.00043
17	8.5	0.57	0.45	0.000357264	0.00044
18	9	0.58	0.46	0.000365204	0.00043
19	9.5	0.57	0.45	0.000357264	0.00044
20	10	0.56	0.44	0.000349325	0.00044
21	10.5	0.56	0.44	0.000349325	0.00044
22	11	0.57	0.45	0.000357264	0.00044
23	11.5	0.56	0.44	0.000349325	0.00044
24	12	0.56	0.44	0.000349325	0.00044
25	12.5	0.56	0.44	0.000349325	0.00044
26	13	0.56	0.44	0.000349325	0.00044
27	13.5	0.57	0.45	0.000357264	0.00044
28	14	0.56	0.44	0.000349325	0.00044
29	14.5	0.55	0.43	0.000341386	0.00045
30	15	0.57	0.45	0.000357264	0.00044
31	15.5	0.55	0.43	0.000341386	0.00045
32	16	0.56	0.44	0.000349325	0.00044
33	16.5	0.55	0.43	0.000341386	0.00045

FYP II FINAL REPORT

34	17	0.56	0.44	0.000349325	0.00044
35	17.5	0.55	0.43	0.000341386	0.00045
36	18	0.56	0.44	0.000349325	0.00044
37	18.5	0.56	0.44	0.000349325	0.00044
38	19	0.56	0.44	0.000349325	0.00044
39	19.5	0.55	0.43	0.000341386	0.00045
40	20	0.55	0.43	0.000341386	0.00045
41	20.5	0.55	0.43	0.000341386	0.00045
42	21	0.56	0.44	0.000349325	0.00044
43	21.5	0.55	0.43	0.000341386	0.00045
44	22	0.56	0.44	0.000349325	0.00044
45	22.5	0.55	0.43	0.000341386	0.00045
46	23	0.56	0.44	0.000349325	0.00044
47	23.5	0.55	0.43	0.000341386	0.00045
48	24	0.55	0.43	0.000341386	0.00045
49	24.5	0.55	0.43	0.000341386	0.00045
50	25	0.55	0.43	0.000341386	0.00045
51	25.5	0.55	0.43	0.000341386	0.00045
52	26	0.56	0.44	0.000349325	0.00044
53	26.5	0.55	0.43	0.000341386	0.00045
54	27	0.54	0.42	0.000333447	0.00046
55	27.5	0.56	0.44	0.000349325	0.00044
56	28	0.54	0.42	0.000333447	0.00046
57	28.5	0.55	0.43	0.000341386	0.00045
58	29	0.55	0.43	0.000341386	0.00045
59	29.5	0.55	0.43	0.000341386	0.00045
60	30	0.55	0.43	0.000341386	0.00045
61	30.5	0.54	0.42	0.000333447	0.00046
62	31	0.55	0.43	0.000341386	0.00045
63	31.5	0.54	0.42	0.000333447	0.00046
64	32	0.55	0.43	0.000341386	0.00045
65	32.5	0.55	0.43	0.000341386	0.00045
66	33	0.54	0.42	0.000333447	0.00046
67	33.5	0.55	0.43	0.000341386	0.00045
68	34	0.55	0.43	0.000341386	0.00045
69	34.5	0.54	0.42	0.000333447	0.00046
70	35	0.55	0.43	0.000341386	0.00045
71	35.5	0.54	0.42	0.000333447	0.00046
72	36	0.54	0.42	0.000333447	0.00046
73	36.5	0.54	0.42	0.000333447	0.00046
74	37	0.54	0.42	0.000333447	0.00046
75	37.5	0.54	0.42	0.000333447	0.00046
76	38	0.55	0.43	0.000341386	0.00045
77	38.5	0.54	0.42	0.000333447	0.00046
78	39	0.54	0.42	0.000333447	0.00046
.79	39.5	0.54	0.42	0.000333447	0.00046
80	40	0.54	0.42	0.000333447	0.00046

81	40.5	0.55	0.43	0.000341386	0.00045
82	41	0.55	0.43	0.000341386	0.00045
83	41.5	0.54	0.42	0.000333447	0.00046
84	42	0.54	0.42	0.000333447	0.00046
85	42.5	0.54	0.42	0.000333447	0.00046
86	43	0.54	0.42	0.000333447	0.00046
87	43.5	0.54	0.42	0.000333447	0.00046
88	44	0.54	0.42	0.000333447	0.00046
89	44.5	0.54	0.42	0.000333447	0.00046
90	45	0.54	0.42	0.000333447	0.00046
91	45.5	0.54	0.42	0.000333447	0.00046
92	46	0.54	0.42	0.000333447	0.00046
93	46.5	0.54	0.42	0.000333447	0.00046
94	47	0.54	0.42	0.000333447	0.00046
95	47.5	0.54	0.42	0.000333447	0.00046
96	48	0.54	0.42	0.000333447	0.00046
97	48.5	0.54	0.42	0.000333447	0.00046
98	49	0.54	0.42	0.000333447	0.00046
99	49.5	0.54	0.42	0.000333447	0.00046
100	50	0.54	0.42	0.000333447	0.00046
101	50.5	0.54	0.42	0.000333447	0.00046
102	51	0.54	0.42	0.000333447	0.00046
103	51.5	0.54	0.42	0.000333447	0.00046
104	52	0.54	0.42	0.000333447	0.00046
105	52.5	0.54	0.42	0.000333447	0.00046
106	53	0.54	0.42	0.000333447	0.00046
107	53.5	0.54	0.42	0.000333447	0.00046
108	54	0.54	0.42	0.000333447	0.00046
109	54.5	0.54	0.42	0.000333447	0.00046
110	55	0.54	0.42	0.000333447	0.00046
111	55.5	0.54	0.42	0.000333447	0.00046
112	56	0.54	0.42	0.000333447	0.00046
113	56.5	0.54	0.42	0.000333447	0.00046
114	57	0.54	0.42	0.000333447	0.00046
115	57.5	0.54	0.42	0.000333447	0.00046
116	58	0.54	0.42	0.000333447	0.00046
117	58.5	0.54	0.42	0.000333447	0.00046
118	59	0.54	0.42	0.000333447	0.00046
119	59.5	0.54	0.42	0.000333447	0.00046
120	60	0.54	0.42	0.000333447	0.00046

Type of Amine	Methyl Diethanolamine / Diethanolamine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02 (initial)	n CO2/ n amine
1	0.5	1.18	1	0.000744762	0.00000
2	1	1.14	0.96	0.000714971	0.00003
3	1.5	1.1	0.92	0.000685181	0.00006
4	2	1.09	0.91	0.000677733	0.00007
5	2.5	1.08	0.9	0.000670286	0.00007
6	3	1.07	0.89	0.000662838	0.00008
7	3.5	1.06	0.88	0.00065539	0.00009
8	4	1.05	0.87	0.000647943	0.00010
9	4.5	1.04	0.86	0.000640495	0.00010
10	5	1.03	0.85	0.000633048	0.00011
11	5.5	1.03	0.85	0.000633048	0.00011
12	6	1.01	0.83	0.000618152	0.00013
13	6.5	0.99	0.81	0.000603257	0.00014
14	7	0.97	0.79	0.000588362	0.00016
15	7.5	0.94	0.76	0.000566019	0.00018
16	8	0.93	0.75	0.000558571	0.00019
17	8.5	0.9	0.72	0.000536229	0.00021
18	9	0.87	0.69	0.000513886	0.00023
19	9.5	0.86	0.68	0.000506438	0.00024
20	10	0.85	0.67	0.00049899	0.00025
21	10.5	0.83	0.65	0.000484095	0.00026
22	11	0.82	0.64	0.000476648	0.00027
23	11.5	0.81	0.63	0.0004692	0.00028
24	12	0.79	0.61	0.000454305	0.00029
25	12.5	0.77	0.59	0.00043941	0.00031
26	13	0.75	0.57	0.000424514	0.00032
27	13.5	0.74	0.56	0.000417067	0.00033
28	14	0.74	0.56	0.000417067	0.00033
29	14.5	0.74	0.56	0.000417067	0.00033
30	15	0.74	0.56	0.000417067	0.00033
31	15.5	0.74	0.56	0.000417067	0.00033
32	16	0.74	0.56	0.000417067	0.00033
33	16.5	0.74	0.56	0.000417067	0.00033
34	17	0.74	0.56	0.000417067	0.00033
35	17.5	0.74	0.56	0.000417067	0.00033
36	18	0.74	0.56	0.000417067	0.00033
37	18.5	0.74	0.56	0.000417067	0.00033
38	19	0.73	0.55	0.000409619	0.00034
39	19.5	0.73	0.55	0.000409619	0.00034
40	20	0.73	0.55	0.000409619	0.00034
41	20.5	0.73	0.55	0.000409619	0.00034
42	21	0.73	0.55	0.000409619	0.00034
43	21.5	0.73	0.55	0.000409619	0.00034
44	22	0.73	0.54	0.000402171	0.00034
45	22.5	0.73	0.55	0.000409619	0.00034
46	23	0.73	0.55	0.000409619	0.00034
47	23.5	0.73	0.55	0.000409619	0.00034
48	24	0.73	0.55	0.000409619	0.00034

49	24.5	0.73	0.55	0.000409619	0.00034
50	25	0.73	0.55	0.000409619	0.00034
51	25.5	0.73	0.55	0.000409619	0.00034
52	26	0.73	0.55	0.000409619	0.00034
53	26.5	0.73	0.55	0.000409619	0.00034
54	27	0.73	0.55	0.000409619	0.00034
55	27.5	0.73	0.55	0.000409619	0.00034
56	28	0.73	0.55	0.000409619	0.00034
57	28.5	0.73	0.55	0.000409619	0.00034
58	29	0.73	0.55	0.000409619	0.00034
59	29.5	0.72	0.54	0.000402171	0.00034
60	30	0.72	0.54	0.000402171	0.00034
61	30.5	0.72	0.54	0.000402171	0.00034
62	31	0.73	0.55	0.000409619	0.00034
63	31.5	0.73	0.55	0.000409619	0.00034
64	32	0.73	0.55	0.000409619	0.00034
65	32.5	0.73	0.55	0.000409619	0.00034
66	33	0.72	0.54	0.000402171	0.00034
67	33.5	0.72	0.54	0.000402171	0.00034
68	34	0.72	0.54	0.000402171	0.00034
69	34.5	0.72	0.54	0.000402171	0.00034
70	35	0.72	0.54	0.000402171	0.00034
71	35.5	0.72	0.54	0.000402171	0.00034
72	36	0.72	0.54	0.000402171	0.00034
73	36.5	0.72	0.54	0.000402171	0.00034
74	37	0.72	0.54	0.000402171	0.00034
75	37.5	0.71	0.53	0.000394724	0.00035
76	38	0.71	0.53	0.000394724	0.00035
77	38.5	0.71	0.53	0.000394724	0.00035
78	39	0.71	0.53	0.000394724	0.00035
79	39.5	0.71	0.53	0.000394724	0.00035
80	40	0.71	0.53	0.000394724	0.00035
81	40.5	0.71	0.53	0.000394724	0.00035
82	41	0.71	0.53	0.000394724	0.00035
83	41.5	0.71	0.53	0.000394724	0.00035
84	42	0.71	0.53	0.000394724	0.00035
85	42.5	0.71	0.53	0.000394724	0.00035
86	43	0.71	0.53	0.000394724	0.00035
87	43.5	0.71	0.53	0.000394724	0.00035
88	44	0.71	0.53	0.000394724	0.00035
89	44.5	0.71	0.53	0.000394724	0.00035
90	45	0.71	0.53	0.000394724	0.00035
91	45.5	0.71	0.53	0.000394724	0.00035
92	46	0.71	0.53	0.000394724	0.00035
93	46.5	0.71	0.53	0.000394724	0.00035
94	47	0.71	0.53	0.000394724	0.00035
95	47.5	0.71	0.53	0.000394724	0.00035
96	48	0.71	0.53	0.000394724	0.00035
97	48.5	0.71	0.53	0.000394724	0.00035

98	49	0.71	0.53	0.000394724	0.00035
99	49.5	0.72	0.54	0.000402171	0.00034
100	50	0.72	0.54	0.000402171	0.00034
101	50.5	0.72	0.54	0.000402171	0.00034
102	51	0.72	0.54	0.000402171	0.00034
103	51.5	0.72	0.54	0.000402171	0.00034
104	52	0.72	0.54	0.000402171	0.00034
105	52.5	0.72	0.54	0.000402171	0.00034
106	53	0.71	0.53	0.000394724	0.00035
107	53.5	0.71	0.53	0.000394724	0.00035
108	54	0.71	0.53	0.000394724	0.00035
109	54.5	0.71	0.53	0.000394724	0.00035
110	55	0.71	0.53	0.000394724	0.00035
111	55.5	0.71	0.53	0.000394724	0.00035
112	56	0.71	0.53	0.000394724	0.00035
113	56.5	0.71	0.53	0.000394724	0.00035
114	57	0.71	0.53	0.000394724	0.00035
115	57.5	0.71	0.53	0.000394724	0.00035
116	58	0.71	0.53	0.000394724	0.00035
117	58.5	0.71	0.53	0.000394724	0.00035
118	59	0.71	0.53	0.000394724	0.00035
119	59.5	0.71	0.53	0.000394724	0.00035
120	60	0.71	0.53	0.000394724	0.00035

Type of Amine	Methyl Diethanolamine / Piperazine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02	n CO2/ n amine
1	0.5	1.02	1	0.000744762	0.00000
2	1	0.82	0.8	0.00059581	0.00015
3	1.5	0.68	0.66	0.000491543	0.00025
4	2	0.67	0.65	0.000484095	0.00026
5	2.5	0.67	0.65	0.000484095	0.00026
6	3	0.66	0.64	0.000476648	0.00027
7	3.5	0.67	0.65	0.000484095	0.00026
8	4	0.67	0.65	0.000484095	0.00026
9	4.5	0.66	0.64	0.000476648	0.00027
10	5	0.66	0.64	0.000476648	0.00027
11	5.5	0.66	0.64	0.000476648	0.00027
12	6	0.67	0.65	0.000484095	0.00026
13	6.5	0.66	0.64	0.000476648	0.00027
14	7	0.66	0.64	0.000476648	0.00027
15	7.5	0.66	0.64	0.000476648	0.00027
16	8	0.65	0.63	0.0004692	0.00028
17	8.5	0.66	0.64	0.000476648	0.00027

18	9	0.66	0.64	0.000476648	0.00027
19	9.5	0.66	0.64	0.000476648	0.00027
20	10	0.65	0.63	0.0004692	0.00028
21	10.5	0.66	0.64	0.000476648	0.00027
22	11	0.65	0.63	0.0004692	0.00028
23	11.5	0.66	0.64	0.000476648	0.00027
24	12	0.65	0.63	0.0004692	0.00028
25	12.5	0.66	0.64	0.000476648	0.00027
26	13	0.65	0.63	0.0004692	0.00028
27	13.5	0.65	0.63	0.0004692	0.00028
28	14	0.65	0.63	0.0004692	0.00028
29	14.5	0.65	0.63	0.0004692	0.00028
30	15	0.65	0.63	0.0004692	0.00028
31	15.5	0.65	0.63	0.0004692	0.00028
32	16	0.65	0.63	0.0004692	0.00028
33	16.5	0.65	0.63	0.0004692	0.00028
34	17	0.65	0.63	0.0004692	0.00028
35	17.5	0.65	0.63	0.0004692	0.00028
36	18	0.65	0.63	0.0004692	0.00028
37	18.5	0.65	0.63	0.0004692	0.00028
38	19	0.64	0.62	0.000461752	0.00028
39	19.5	0.65	0.63	0.0004692	0.00028
40	20	0.65	0.63	0.0004692	0.00028
41	20.5	0.64	0.62	0.000461752	0.00028
42	21	0.64	0.62	0.000461752	0.00028
43	21.5	0.64	0.62	0.000461752	0.00028
44	22	0.64	0.62	0.000461752	0.00028
45	22.5	0.64	0.62	0.000461752	0.00028
46	23	0.65	0.63	0.0004692	0.00028
47	23.5	0.64	0.62	0.000461752	0.00028
48	24	0.65	0.63	0.0004692	0.00028
49	24.5	0.64	0.62	0.000461752	0.00028
50	25	0.64	0.62	0.000461752	0.00028
51	25.5	0.63	0.61	0.000454305	0.00029
52	26	0.65	0.63	0.0004692	0.00028
53	26.5	0.64	0.62	0.000461752	0.00028
54	27	0.64	0.62	0.000461752	0.00028
55	27.5	0.64	0.62	0.000461752	0.00028
56	28	0.64	0.62	0.000461752	0.00028
57	28.5	0.64	0.62	0.000461752	0.00028
58	29	0.64	0.62	0.000461752	0.00028
59	29.5	0.63	0.61	0.000454305	0.00029
60	30	0.64	0.62	0.000461752	0.00028
61	30.5	0.64	0.62	0.000461752	0.00028
62	31	0.63	0.61	0.000454305	0.00029
63	31.5	0.63	0.61	0.000454305	0.00029
64	32	0.63	0.61	0.000454305	0.00029
65	32.5	0.63	0.61	0.000454305	0.00029
66	33	0.63	0.61	0.000454305	0.00029

FYP II FINAL REPORT

67	33.5	0.63	0.61	0.000454305	0.00029
68	34	0.63	0.61	0.000454305	0.00029
69	34.5	0.63	0.61	0.000454305	0.00029
70	35	0.63	0.61	0.000454305	0.00029
71	35.5	0.63	0.61	0.000454305	0.00029
72	36	0.63	0.61	0.000454305	0.00029
73	36.5	0.63	0.61	0.000454305	0.00029
74	37	0.63	0.61	0.000454305	0.00029
75	37.5	0.63	0.61	0.000454305	0.00029
76	38	0.63	0.61	0.000454305	0.00029
77	38.5	0.63	0.61	0.000454305	0.00029
78	39	0.63	0.61	0.000454305	0.00029
79	39.5	0.63	0.61	0.000454305	0.00029
80	40	0.63	0.61	0.000454305	0.00029
81	40.5	0.63	0.61	0.000454305	0.00029
82	41	0.63	0.61	0.000454305	0.00029
83	41.5	0.63	0.61	0.000454305	0.00029
84	42	0.63	0.61	0.000454305	0.00029
85	42.5	0.63	0.61	0.000454305	0.00029
86	43	0.63	0.61	0.000454305	0.00029
87	43.5	0.63	0.61	0.000454305	0.00029
88	44	0.63	0.61	0.000454305	0.00029
89	44.5	0.63	0.61	0.000454305	0.00029
90	45	0.63	0.61	0.000454305	0.00029
91	45.5	0.63	0.61	0.000454305	0.00029
92	46	0.63	0.61	0.000454305	0.00029
93	46.5	0.63	0.61	0.000454305	0.00029
94	47	0.63	0.61	0.000454305	0.00029
95	47.5	0.63	0.61	0.000454305	0.00029
96	48	0.63	0.61	0.000454305	0.00029
97	48.5	0.63	0.61	0.000454305	0.00029
98	49	0.63	0.61	0.000454305	0.00029
99	49.5	0.63	0.61	0.000454305	0.00029
100	50	0.63	0.61	0.000454305	0.00029
101	50.5	0.63	0.61	0.000454305	0.00029
102	51	0.63	0.61	0.000454305	0.00029
103	51.5	0.63	0.61	0.000454305	0.00029
104	52	0.63	0.61	0.000454305	0.00029
105	52.5	0.63	0.61	0.000454305	0.00029
106	53	0.63	0.61	0.000454305	0.00029
107	53.5	0.63	0.61	0.000454305	0.00029
108	54	0.63	0.61	0.000454305	0.00029
109	54.5	0.63	0.61	0.000454305	0.00029
110	55	0.63	0.61	0.000454305	0.00029
111	55.5	0.63	0.61	0.000454305	0.00029
112	56	0.63	0.61	0.000454305	0.00029
113	56.5	0.63	0.61	0.000454305	0.00029
114	57	0.63	0.61	0.000454305	0.00029
115	57.5	0.63	0.61	0.000454305	0.00029

116	58	0.63	0.61	0.000454305	0.00029
117	58.5	0.63	0.61	0.000454305	0.00029
118	59	0.63	0.61	0.000454305	0.00029
119	59.5	0.63	0.61	0.000454305	0.00029
120	60	0.63	0.61	0.000454305	0.00029

Type of Amine	Methyl Diethanolamine / Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02	n C02/ n amine
1	0.5	1.04	1	0.000793921	0.00000
2	1	0.65	0.61	0.000484292	0.00031
3	1.5	0.58	0.54	0.000428717	0.00037
4	2	0.58	0.54	0.000428717	0.00037
5	2.5	0.57	0.53	0.000420778	0.00037
6	3	0.57	0.53	0.000420778	0.00037
7	3.5	0.57	0.53	0.000420778	0.00037
8	4	0.56	0.52	0.000412839	0.00038
9	4.5	0.57	0.53	0.000420778	0.00037
10	5	0.57	0.53	0.000420778	0.00037
11	5.5	0.57	0.53	0.000420778	0.00037
12	6	0.58	0.54	0.000428717	0.00037
13	6.5	0.56	0.52	0.000412839	0.00038
14	7	0.56	0.52	0.000412839	0.00038
15	7.5	0.56	0.52	0.000412839	0.00038
16	8	0.56	0.52	0.000412839	0.00038
17	8.5	0.56	0.52	0.000412839	0.00038
18	9	0.56	0.52	0.000412839	0.00038
19	9.5	0.56	0.52	0.000412839	0.00038
20	10	0.57	0.53	0.000420778	0.00037
21	10.5	0.56	0.52	0.000412839	0.00038
22	11	0.56	0.52	0.000412839	0.00038
23	11.5	0.56	0.52	0.000412839	0.00038
24	12	0.56	0.52	0.000412839	0.00038
25	12.5	0.55	0.51	0.0004049	0.00039
26	13	0.56	0.52	0.000412839	0.00038
27	13.5	0.57	0.53	0.000420778	0.00037
28	14	0.56	0.52	0.000412839	0.00038
29	14.5	0.55	0.51	0.0004049	0.00039
30	15	0.55	0.51	0.0004049	0.00039
31	15.5	0.55	0.51	0.0004049	0.00039
32	16	0.55	0.51	0.0004049	0.00039
33	16.5	0.56	0.52	0.000412839	0.00038
34	17	0.56	0.52	0.000412839	0.00038
35	17.5	0.55	0.51	0.0004049	0.00039

FYP II FINAL REPORT

36	18	0.55	0.51	0.0004049	0.00039
37	18.5	0.55	0.51	0.0004049	0.00039
38	19	0.55	0.51	0.0004049	0.00039
39	19.5	0.55	0.51	0.0004049	0.00039
40	20	0.56	0.52	0.000412839	0.00038
41	20.5	0.55	0.51	0.0004049	0.00039
42	21	0.55	0.51	0.0004049	0.00039
43	21.5	0.55	0.51	0.0004049	0.00039
44	22	0.55	0.51	0.0004049	0.00039
45	22.5	0.54	0.5	0.000396961	0.00040
46	23	0.55	0.51	0.0004049	0.00039
47	23.5	0.54	0.5	0.000396961	0.00040
48	24	0.55	0.51	0.0004049	0.00039
49	24.5	0.55	0.51	0.0004049	0.00039
50	25	0.55	0.51	0.0004049	0.00039
51	25.5	0.55	0.51	0.0004049	0.00039
52	26	0.54	0.5	0.000396961	0.00040
53	26.5	0.55	0.51	0.0004049	0.00039
54	27	0.54	0.5	0.000396961	0.00040
55	27.5	0.54	0.5	0.000396961	0.00040
56	28	0.54	0.5	0.000396961	0.00040
57	28.5	0.55	0.51	0.0004049	0.00039
58	29	0.54	0.5	0.000396961	0.00040
59	29.5	0.54	0.5	0.000396961	0.00040
60	30	0.55	0.51	0.0004049	0.00039
61	30.5	0.55	0.51	0.0004049	0.00039
62	31	0.54	0.5	0.000396961	0.00040
63	31.5	0.54	0.5	0.000396961	0.00040
64	32	0.54	0.5	0.000396961	0.00040
65	32.5	0.54	0.5	0.000396961	0.00040
66	33	0.54	0.5	0.000396961	0.00040
67	33.5	0.54	0.5	0.000396961	0.00040
68	34	0.54	0.5	0.000396961	0.00040
69	34.5	0.55	0.51	0.0004049	0.00039
70	35	0.54	0.5	0.000396961	0.00040
71	35.5	0.54	0.5	0.000396961	0.00040
72	36	0.54	0.5	0.000396961	0.00040
73	36.5	0.54	0.5	0.000396961	0.00040
74	37	0.54	0.5	0.000396961	0.00040
75	37.5	0.54	0.5	0.000396961	0.00040
76	38	0.54	0.5	0.000396961	0.00040
77	38.5	0.54	0.5	0.000396961	0.00040
78	39	0.54	0.5	0.000396961	0.00040
79	39.5	0.54	0.5	0.000396961	0.00040
80	40	0.54	0.5	0.000396961	0.00040
81	40.5	0.54	0.5	0.000396961	0.00040
82	41	0.54	0.5	0.000396961	0.00040
83	41.5	0.54	0.5	0.000396961	0.00040
84	42	0.54	0.5	0.000396961	0.00040

85	42.5	0.54	0.5	0.000396961	0.00040
86	43	0.54	0.5	0.000396961	0.00040
87	43.5	0.54	0.5	0.000396961	0.00040
88	44	0.54	0.5	0.000396961	0.00040
89	44.5	0.54	0.5	0.000396961	0.00040
90	45	0.54	0.5	0.000396961	0.00040
91	45.5	0.54	0.5	0.000396961	0.00040
92	46	0.54	0.5	0.000396961	0.00040
93	46.5	0.54	0.5	0.000396961	0.00040
94	47	0.54	0.5	0.000396961	0.00040
95	47.5	0.54	0.5	0.000396961	0.00040
96	48	0.54	0.5	0.000396961	0.00040
97	48.5	0.54	0.5	0.000396961	0.00040
98	49	0.54	0.5	0.000396961	0.00040
99	49.5	0.54	0.5	0.000396961	0.00040
100	50	0.54	0.5	0.000396961	0.00040
101	50.5	0.54	0.5	0.000396961	0.00040
102	51	0.54	0.5	0.000396961	0.00040
103	51.5	0.54	0.5	0.000396961	0.00040
104	52	0.54	0.5	0.000396961	0.00040
105	52.5	0.54	0.5	0.000396961	0.00040
106	53	0.54	0.5	0.000396961	0.00040
107	53.5	0.54	0.5	0.000396961	0.00040
108	54	0.54	0.5	0.000396961	0.00040
109	54.5	0.54	0.5	0.000396961	0.00040
110	55	0.54	0.5	0.000396961	0.00040
111	55.5	0.54	0.5	0.000396961	0.00040
112	56	0.54	0.5	0.000396961	0.00040
113	56.5	0.54	0.5	0.000396961	0.00040
114	57	0.54	0.5	0.000396961	0.00040
115	57.5	0.54	0.5	0.000396961	0.00040
116	58	0.54	0.5	0.000396961	0.00040
117	58.5	0.54	0.5	0.000396961	0.00040
118	59	0.54	0.5	0.000396961	0.00040
119	59.5	0.54	0.5	0.000396961	0.00040
120	60	0.54	0.5	0.000396961	0.00040

Type of Amine	Methyl Diethanolamine / Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02	n CO2/ n amine
1	0.5	1.04	1	0.000744762	0.00000
2	1	0.64	0.6	0.000446857	0.00030
3	1.5	0.63	0.59	0.00043941	0.00031
4	2	0.63	0.59	0.00043941	0.00031
5	2.5	0.63	0.59	0.00043941	0.00031

FYP II FINAL REPORT

6	3	0.62	0.58	0.000431962	0.00031
7	3.5	0.63	0.59	0.00043941	0.00031
8	4	0.63	0.59	0.00043941	0.00031
9	4.5	0.64	0.6	0.000446857	0.00030
10	5	0.63	0.59	0.00043941	0.00031
11	5.5	0.63	0.59	0.00043941	0.00031
12	6	0.63	0.59	0.00043941	0.00031
13	6.5	0.62	0.58	0.000431962	0.00031
14	7	0.63	0.59	0.00043941	0.00031
15	7.5	0.62	0.58	0.000431962	0.00031
16	8	0.63	0.59	0.00043941	0.00031
17	8.5	0.62	0.58	0.000431962	0.00031
18	9	0.62	0.58	0.000431962	0.00031
19	9.5	0.62	0.58	0.000431962	0.00031
20	10	0.61	0.57	0.000424514	0.00032
21	10.5	0.63	0.59	0.00043941	0.00031
22	11	0.62	0.58	0.000431962	0.00031
23	11.5	0.62	0.58	0.000431962	0.00031
24	12	0.62	0.58	0.000431962	0.00031
25	12.5	0.62	0.58	0.000431962	0.00031
26	13	0.62	0.58	0.000431962	0.00031
27	13.5	0.62	0.58	0.000431962	0.00031
28	14	0.62	0.58	0.000431962	0.00031
29	14.5	0.61	0.57	0.000424514	0.00032
30	15	0.62	0.58	0.000431962	0.00031
31	15.5	0.61	0.57	0.000424514	0.00032
32	16	0.62	0.58	0.000431962	0.00031
33	16.5	0.62	0.58	0.000431962	0.00031
34	17	0.61	0.57	0.000424514	0.00032
35	17.5	0.62	0.58	0.000431962	0.00031
36	18	0.62	0.58	0.000431962	0.00031
37	18.5	0.61	0.57	0.000424514	0.00032
38	19	0.62	0.58	0.000431962	0.00031
39	19.5	0.61	0.57	0.000424514	0.00032
40	20	0.61	0.57	0.000424514	0.00032
41	20.5	0.62	0.58	0.000431962	0.00031
42	21	0.6	0.56	0.000417067	0.00033
43	21.5	0.61	0.57	0.000424514	0.00032
44	22	0.62	0.58	0.000431962	0.00031
45	22.5	0.61	0.57	0.000424514	0.00032
46	23	0.61	0.57	0.000424514	0.00032
47	23.5	0.61	0.57	0.000424514	0.00032
48	24	0.62	0.58	0.000431962	0.00031
49	24.5	0.61	0.57	0.000424514	0.00032
50	25	0.62	0.58	0.000431962	0.00031
51	25.5	0.61	0.57	0.000424514	0.00032
52	26	0.6	0.56	0.000417067	0.00033
53	26.5	0.61	0.57	0.000424514	0.00032
54	27	0.61	0.57	0.000424514	0.00032

55	27.5	0.61	0.57	0.000424514	0.00032
56	28	0.61	0.57	0.000424514	0.00032
57	28.5	0.61	0.57	0.000424514	0.00032
58	29	0.61	0.57	0.000424514	0.00032
59	29.5	0.61	0.57	0.000424514	0.00032
60	30	0.61	0.57	0.000424514	0.00032
61	30.5	0.61	0.57	0.000424514	0.00032
62	31	0.6	0.56	0.000417067	0.00033
63	31.5	0.61	0.57	0.000424514	0.00032
64	32	0.61	0.57	0.000424514	0.00032
65	32.5	0.6	0.56	0.000417067	0.00033
66	33	0.61	0.57	0.000424514	0.00032
67	33.5	0.61	0.57	0.000424514	0.00032
68	34	0.61	0.57	0.000424514	0.00032
69	34.5	0.6	0.56	0.000417067	0.00033
70	35	0.61	0.57	0.000424514	0.00032
71	35.5	0.6	0.56	0.000417067	0.00033
72	36	0.61	0.57	0.000424514	0.00032
73	36.5	0.6	0.56	0.000417067	0.00033
74	37	0.61	0.57	0.000424514	0.00032
75	37.5	0.6	0.56	0.000417067	0.00033
76	38	0.6	0.56	0.000417067	0.00033
77	38.5	0.6	0.56	0.000417067	0.00033
78	39	0.6	0.56	0.000417067	0.00033
79	39.5	0.6	0.56	0.000417067	0.00033
80	40	0.61	0.57	0.000424514	0.00032
81	40.5	0.6	0.56	0.000417067	0.00033
82	41	0.6	0.56	0.000417067	0.00033
83	41.5	0.6	0.56	0.000417067	0.00033
84	42	0.6	0.56	0.000417067	0.00033
85	42.5	0.6	0.56	0.000417067	0.00033
86	43	0.6	0.56	0.000417067	0.00033
87	43.5	0.61	0.57	0.000424514	0.00032
88	44	0.6	0.56	0.000417067	0.00033
89	44.5	0.6	0.56	0.000417067	0.00033
90	45	0.6	0.56	0.000417067	0.00033
91	45.5	0.61	0.57	0.000424514	0.00032
92	46	0.61	0.57	0.000424514	0.00032
93	46.5	0.6	0.56	0.000417067	0.00033
94	47	0.6	0.56	0.000417067	0.00033
95	47.5	0.6	0.56	0.000417067	0.00033
96	48	0.6	0.56	0.000417067	0.00033
97	48.5	0.6	0.56	0.000417067	0.00033
98	49	0.6	0.56	0.000417067	0.00033
99	49.5	0.6	0.56	0.000417067	0.00033
100	50	0.6	0.56	0.000417067	0.00033
101	50.5	0.6	0.56	0.000417067	0.00033
102	51	0.6	0.56	0.000417067	0.00033
103	51.5	0.6	0.56	0.000417067	0.00033

104	52	0.6	0.56	0.000417067	0.00033
105	52.5	0.6	0.56	0.000417067	0.00033
106	53	0.6	0.56	0.000417067	0.00033
107	53.5	0.6	0.56	0.000417067	0.00033
108	54	0.6	0.56	0.000417067	0.00033
109	54.5	0.6	0.56	0.000417067	0.00033
110	55	0.6	0.56	0.000417067	0.00033
111	55.5	0.6	0.56	0.000417067	0.00033
112	56	0.6	0.56	0.000417067	0.00033
113	56.5	0.6	0.56	0.000417067	0.00033
114	57	0.6	0.56	0.000417067	0.00033
115	57.5	0.6	0.56	0.000417067	0.00033
116	58	0.6	0.56	0.000417067	0.00033
117	58.5	0.6	0.56	0.000417067	0.00033
118	59	0.6	0.56	0.000417067	0.00033
119	59.5	0.6	0.56	0.000417067	0.00033
120	60	0.6	0.56	0.000417067	0.00033

Type of Amine	Methyl Diethanolamine / Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02	n C02 / n amine
1	0.5	1.06	1	0.000793921	0.00000
2	1	1.01	0.95	0.000754225	0.00004
3	1.5	0.75	0.69	0.000547806	0.00025
4	2	0.68	0.62	0.000492231	0.00030
5	2.5	0.65	0.59	0.000468413	0.00033
6	3	0.59	0.53	0.000420778	0.00037
7	3.5	0.58	0.52	0.000412839	0.00038
8	4	0.57	0.51	0.0004049	0.00039
9	4.5	0.56	0.5	0.000396961	0.00040
10	5	0.55	0.49	0.000389021	0.00040
11	5.5	0.55	0.49	0.000389021	0.00040
12	6	0.54	0.48	0.000381082	0.00041
13	6.5	0.54	0.48	0.000381082	0.00041
14	7	0.54	0.48	0.000381082	0.00041
15	7.5	0.54	0.48	0.000381082	0.00041
16	8	0.54	0.48	0.000381082	0.00041
17	8.5	0.54	0.48	0.000381082	0.00041
18	9	0.54	0.48	0.000381082	0.00041
19	9.5	0.53	0.47	0.000373143	0.00042
20	10	0.53	0.47	0.000373143	0.00042
21	10.5	0.53	0.47	0.000373143	0.00042
22	11	0.54	0.48	0.000381082	0.00041

23	11.5	0.53	0.47	0.000373143	0.00042
24	12	0.53	0.47	0.000373143	0.00042
25	12.5	0.53	0.47	0.000373143	0.00042
26	13	0.53	0.47	0.000373143	0.00042
27	13.5	0.53	0.47	0.000373143	0.00042
28	14	0.53	0.47	0.000373143	0.00042
29	14.5	0.52	0.46	0.000365204	0.00043
30	15	0.53	0.47	0.000373143	0.00042
31	15.5	0.52	0.46	0.000365204	0.00043
32	16	0.52	0.46	0.000365204	0.00043
33	16.5	0.53	0.47	0.000373143	0.00042
34	17	0.52	0.46	0.000365204	0.00043
35	17.5	0.52	0.46	0.000365204	0.00043
36	18	0.52	0.46	0.000365204	0.00043
37	18.5	0.52	0.46	0.000365204	0.00043
38	19	0.52	0.46	0.000365204	0.00043
39	19.5	0.52	0.46	0.000365204	0.00043
40	20	0.52	0.46	0.000365204	0.00043
41	20.5	0.52	0.46	0.000365204	0.00043
42	21	0.52	0.46	0.000365204	0.00043
43	21.5	0.53	0.47	0.000373143	0.00042
44	22	0.51	0.45	0.000357264	0.00044
45	22.5	0.51	0.45	0.000357264	0.00044
46	23	0.52	0.46	0.000365204	0.00043
47	23.5	0.52	0.46	0.000365204	0.00043
48	24	0.52	0.46	0.000365204	0.00043
49	24.5	0.52	0.46	0.000365204	0.00043
50	25	0.51	0.45	0.000357264	0.00044
51	25.5	0.52	0.46	0.000365204	0.00043
52	26	0.51	0.45	0.000357264	0.00044
53	26.5	0.52	0.46	0.000365204	0.00043
54	27	0.52	0.46	0.000365204	0.00043
55	27.5	0.52	0.46	0.000365204	0.00043
56	28	0.52	0.46	0.000365204	0.00043
57	28.5	0.51	0.45	0.000357264	0.00044
58	29	0.51	0.45	0.000357264	0.00044
59	29.5	0.51	0.45	0.000357264	0.00044
60	30	0.51	0.45	0.000357264	0.00044
61	30.5	0.51	0.45	0.000357264	0.00044
62	31	0.51	0.45	0.000357264	0.00044
63	31.5	0.51	0.45	0.000357264	0.00044
64	32	0.51	0.45	0.000357264	0.00044
65	32.5	0.51	0.45	0.000357264	0.00044
66	33	0.51	0.45	0.000357264	0.00044
67	33.5	0.51	0.44	0.000349325	0.00044
68	34	0.51	0.45	0.000357264	0.00044
69	34.5	0.51	0.43	0.000341386	0.00045
70	35	0.51	0.44	0.000349325	0.00044
71	35.5	0.51	0.44	0.000349325	0.00044

FYP II FINAL REPORT

72	36	0.51	0.44	0.000349325	0.00044
73	36.5	0.51	0.44	0.000349325	0.00044
74	37	0.51	0.43	0.000341386	0.00045
75	37.5	0.51	0.44	0.000349325	0.00044
76	38	0.51	0.44	0.000349325	0.00044
77	38.5	0.51	0.44	0.000349325	0.00044
78	39	0.51	0.43	0.000341386	0.00045
79	39.5	0.51	0.43	0.000341386	0.00045
80	40	0.51	0.43	0.000341386	0.00045
81	40.5	0.51	0.43	0.000341386	0.00045
82	41	0.51	0.43	0.000341386	0.00045
83	41.5	0.51	0.43	0.000341386	0.00045
84	42	0.51	0.43	0.000341386	0.00045
85	42.5	0.51	0.43	0.000341386	0.00045
86	43	0.51	0.42	0.000333447	0.00046
87	43.5	0.51	0.43	0.000341386	0.00045
88	44	0.51	0.43	0.000341386	0.00045
89	44.5	0.51	0.43	0.000341386	0.00045
90	45	0.51	0.43	0.000341386	0.00045
91	45.5	0.51	0.43	0.000341386	0.00045
92	46	0.51	0.43	0.000341386	0.00045
93	46.5	0.51	0.43	0.000341386	0.00045
94	47	0.51	0.43	0.000341386	0.00045
95	47.5	0.51	0.43	0.000341386	0.00045
96	48	0.51	0.43	0.000341386	0.00045
97	48.5	0.51	0.43	0.000341386	0.00045
98	49	0.51	0.43	0.000341386	0.00045
99	49.5	0.51	0.42	0.000333447	0.00046
100	50	0.51	0.42	0.000333447	0.00046
101	50.5	0.51	0.42	0.000333447	0.00046
102	51	0.51	0.42	0.000333447	0.00046
103	51.5	0.51	0.42	0.000333447	0.00046
104	52	0.51	0.43	0.000341386	0.00045
105	52.5	0.51	0.42	0.000333447	0.00046
106	53	0.51	0.41	0.000325508	0.00047
107	53.5	0.51	0.41	0.000325508	0.00047
108	54	0.51	0.41	0.000325508	0.00047
109	54.5	0.51	0.41	0.000325508	0.00047
110	55	0.51	0.41	0.000325508	0.00047
111	55.5	0.51	0.41	0.000325508	0.00047
112	56	0.51	0.41	0.000325508	0.00047
113	56.5	0.51	0.41	0.000325508	0.00047
114	57	0.51	0.41	0.000325508	0.00047
115	57.5	0.51	0.41	0.000325508	0.00047
116	58	0.51	0.41	0.000325508	0.00047
117	58.5	0.51	0.41	0.000325508	0.00047
118	59	0.51	0.41	0.000325508	0.00047
119	59.5	0.51	0.41	0.000325508	0.00047
120	60	0.51	0.41	0.000325508	0.00047

FYP II FINAL REPORT

Type of Amine	Methyl Diethanolamine / Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02	n C02 / n amine
1	0.5	1.06	1	0.000744762	0.00000
2	1	0.88	0.82	0.000610705	0.00013
3	1.5	0.66	0.6	0.000446857	0.00030
4	2	0.63	0.57	0.000424514	0.00032
5	2.5	0.62	0.56	0.000417067	0.00033
6	3	0.62	0.56	0.000417067	0.00033
7	3.5	0.62	0.56	0.000417067	0.00033
8	4	0.62	0.56	0.000417067	0.00033
9	4.5	0.61	0.55	0.000409619	0.00034
10	5	0.61	0.55	0.000409619	0.00034
11	5.5	0.62	0.56	0.000417067	0.00033
12	6	0.61	0.55	0.000409619	0.00034
13	6.5	0.61	0.55	0.000409619	0.00034
14	7	0.6	0.54	0.000402171	0.00034
15	7.5	0.61	0.55	0.000409619	0.00034
16	8	0.61	0.55	0.000409619	0.00034
17	8.5	0.59	0.53	0.000394724	0.00035
18	9	0.6	0.54	0.000402171	0.00034
19	9.5	0.6	0.54	0.000402171	0.00034
20	10	0.6	0.54	0.000402171	0.00034
21	10.5	0.6	0.54	0.000402171	0.00034
22	11	0.59	0.53	0.000394724	0.00035
23	11.5	0.61	0.55	0.000409619	0.00034
24	12	0.6	0.54	0.000402171	0.00034
25	12.5	0.59	0.53	0.000394724	0.00035
26	13	0.6	0.54	0.000402171	0.00034
27	13.5	0.6	0.54	0.000402171	0.00034
28	14	0.6	0.54	0.000402171	0.00034
29	14.5	0.6	0.54	0.000402171	0.00034
30	15	0.59	0.53	0.000394724	0.00035
31	15.5	0.6	0.54	0.000402171	0.00034
32	16	0.6	0.54	0.000402171	0.00034
33	16.5	0.59	0.53	0.000394724	0.00035
34	17	0.59	0.53	0.000394724	0.00035
35	17.5	0.59	0.53	0.000394724	0.00035
36	18	0.59	0.53	0.000394724	0.00035
37	18.5	0.58	0.52	0.000387276	0.00036
38	19	0.59	0.53	0.000394724	0.00035
39	19.5	0.58	0.52	0.000387276	0.00036
40	20	0.58	0.52	0.000387276	0.00036
41	20.5	0.59	0.53	0.000394724	0.00035
42	21	0.58	0.52	0.000387276	0.00036
43	21.5	0.58	0.52	0.000387276	0.00036
44	22	0.58	0.52	0.000387276	0.00036
45	22.5	0.58	0.52	0.000387276	0.00036
46	23	0.58	0.52	0.000387276	0.00036
47	23.5	0.58	0.52	0.000387276	0.00036
48	24	0.57	0.51	0.000379829	0.00036
49	24.5	0.57	0.51	0.000379829	0.00036
50	25	0.58	0.52	0.000387276	0.00036
51	25.5	0.58	0.52	0.000387276	0.00036
52	26	0.58	0.52	0.000387276	0.00036
53	26.5	0.57	0.51	0.000379829	0.00036
54	27	0.57	0.51	0.000379829	0.00036
55	27.5	0.57	0.51	0.000379829	0.00036
56	28	0.57	0.51	0.000379829	0.00036
57	28.5	0.57	0.51	0.000379829	0.00036
58	29	0.57	0.51	0.000379829	0.00036
59	29.5	0.57	0.51	0.000379829	0.00036
60	30	0.58	0.52	0.000387276	0.00036
61	30.5	0.57	0.51	0.000379829	0.00036
62	31	0.58	0.52	0.000387276	0.00036
63	31.5	0.57	0.51	0.000379829	0.00036
64	32	0.57	0.51	0.000379829	0.00036
65	32.5	0.57	0.51	0.000379829	0.00036
66	33	0.57	0.51	0.000379829	0.00036
67	33.5	0.57	0.51	0.000379829	0.00036
68	34	0.57	0.51	0.000379829	0.00036
69	34.5	0.57	0.51	0.000379829	0.00036
70	35	0.57	0.51	0.000379829	0.00036
71	35.5	0.57	0.51	0.000379829	0.00036
72	36	0.57	0.51	0.000379829	0.00036
73	36.5	0.57	0.51	0.000379829	0.00036
74	37	0.57	0.51	0.000379829	0.00036
75	37.5	0.57	0.51	0.000379829	0.00036
76	38	0.57	0.51	0.000379829	0.00036
77	38.5	0.57	0.51	0.000379829	0.00036
78	39	0.57	0.51	0.000379829	0.00036
79	39.5	0.57	0.51	0.000379829	0.00036
80	40	0.57	0.51	0.000379829	0.00036
81	40.5	0.57	0.51	0.000379829	0.00036
82	41	0.57	0.51	0.000379829	0.00036
83	41.5	0.57	0.51	0.000379829	0.00036
84	42	0.57	0.51	0.000379829	0.00036
85	42.5	0.57	0.51	0.000379829	0.00036
86	43	0.57	0.51	0.000379829	0.00036
87	43.5	0.57	0.51	0.000379829	0.00036

88	44	0.57	0.51	0.000379829	0.00036
89	44.5	0.57	0.51	0.000379829	0.00036
90	45	0.57	0.51	0.000379829	0.00036
91	45.5	0.57	0.51	0.000379829	0.00036
92	46	0.57	0.51	0.000379829	0.00036
93	46.5	0.57	0.51	0.000379829	0.00036
94	47	0.57	0.51	0.000379829	0.00036
95	47.5	0.57	0.51	0.000379829	0.00036
96	48	0.57	0.51	0.000379829	0.00036
97	48.5	0.57	0.51	0.000379829	0.00036
98	49	0.57	0.51	0.000379829	0.00036
99	49.5	0.57	0.51	0.000379829	0.00036
100	50	0.57	0.51	0.000379829	0.00036
101	50.5	0.57	0.51	0.000379829	0.00036
102	51	0.57	0.51	0.000379829	0.00036
103	51.5	0.57	0.51	0.000379829	0.00036
104	52	0.57	0.51	0.000379829	0.00036
105	52.5	0.57	0.51	0.000379829	0.00036
106	53	0.57	0.51	0.000379829	0.00036
107	53.5	0.57	0.51	0.000379829	0.00036
108	54	0.57	0.51	0.000379829	0.00036
109	54.5	0.57	0.51	0.000379829	0.00036
110	55	0.57	0.51	0.000379829	0.00036
111	55.5	0.57	0.51	0.000379829	0.00036
112	56	0.57	0.51	0.000379829	0.00036
113	56.5	0.57	0.51	0.000379829	0.00036
114	57	0.57	0.51	0.000379829	0.00036
115	57.5	0.57	0.51	0.000379829	0.00036
116	58	0.57	0.51	0.000379829	0.00036
117	58.5	0.57	0.51	0.000379829	0.00036
118	59	0.57	0.51	0.000379829	0.00036
119	59.5	0.57	0.51	0.000379829	0.00036
120	60	0.57	0.51	0.000379829	0.00036

Type of Amine	Methyl Diethanolamine / Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02	n C02 / n amine
1	0.5	1.12	1	0.000793921	0.00000
2	1	0.73	0.61	0.000484292	0.00031
3	1.5	0.59	0.47	0.000373143	0.00042
4	2	0.58	0.46	0.000365204	0.00043
5	2.5	0.58	0.46	0.000365204	0.00043
6	3	0.58	0.46	0.000365204	0.00043

7	3.5	0.57	0.45	0.000357264	0.00044
8	4	0.58	0.46	0.000365204	0.00043
9	4.5	0.58	0.46	0.000365204	0.00043
10	5	0.57	0.45	0.000357264	0.00044
11	5.5	0.57	0.45	0.000357264	0.00044
12	6	0.57	0.45	0.000357264	0.00044
13	6.5	0.57	0.45	0.000357264	0.00044
14	7	0.57	0.45	0.000357264	0.00044
15	7.5	0.57	0.45	0.000357264	0.00044
16	8	0.57	0.45	0.000357264	0.00044
17	8.5	0.56	0.44	0.000349325	0.00044
18	9	0.57	0.45	0.000357264	0.00044
19	9.5	0.57	0.45	0.000357264	0.00044
20	10	0.56	0.44	0.000349325	0.00044
21	10.5	0.56	0.44	0.000349325	0.00044
22	11	0.56	0.44	0.000349325	0.00044
23	11.5	0.57	0.45	0.000357264	0.00044
24	12	0.56	0.44	0.000349325	0.00044
25	12.5	0.56	0.44	0.000349325	0.00044
26	13	0.56	0.44	0.000349325	0.00044
27	13.5	0.57	0.45	0.000357264	0.00044
28	14	0.56	0.44	0.000349325	0.00044
29	14.5	0.56	0.44	0.000349325	0.00044
30	15	0.56	0.44	0.000349325	0.00044
31	15.5	0.56	0.44	0.000349325	0.00044
32	16	0.56	0.44	0.000349325	0.00044
33	16.5	0.55	0.43	0.000341386	0.00045
34	17	0.56	0.44	0.000349325	0.00044
35	17.5	0.55	0.43	0.000341386	0.00045
36	18	0.56	0.44	0.000349325	0.00044
37	18.5	0.56	0.44	0.000349325	0.00044
38	19	0.56	0.44	0.000349325	0.00044
39	19.5	0.55	0.43	0.000341386	0.00045
40	20	0.56	0.44	0.000349325	0.00044
41	20.5	0.55	0.43	0.000341386	0.00045
42	21	0.56	0.44	0.000349325	0.00044
43	21.5	0.55	0.43	0.000341386	0.00045
44	22	0.56	0.44	0.000349325	0.00044
45	22.5	0.55	0.43	0.000341386	0.00045
46	23	0.55	0.43	0.000341386	0.00045
47	23.5	0.55	0.43	0.000341386	0.00045
48	24	0.54	0.42	0.000333447	0.00046
49	24.5	0.55	0.43	0.000341386	0.00045
50	25	0.54	0.42	0.000333447	0.00046
51	25.5	0.55	0.43	0.000341386	0.00045
52	26	0.54	0.42	0.000333447	0.00046
53	26.5	0.55	0.43	0.000341386	0.00045

54	27	0.53	0.41	0.000325508	0.00047
55	27.5	0.54	0.42	0.000333447	0.00046
56	28	0.53	0.41	0.000325508	0.00047
57	28.5	0.53	0.41	0.000325508	0.00047
58	29	0.53	0.41	0.000325508	0.00047
59	29.5	0.52	0.4	0.000317568	0.00048
60	30	0.53	0.41	0.000325508	0.00047
61	30.5	0.51	0.39	0.000309629	0.00048
62	31	0.5	0.38	0.00030169	0.00049
63	31.5	0.52	0.4	0.000317568	0.00048
64	32	0.52	0.4	0.000317568	0.00048
65	32.5	0.52	0.4	0.000317568	0.00048
66	33	0.51	0.39	0.000309629	0.00048
67	33.5	0.51	0.39	0.000309629	0.00048
68	34	0.51	0.39	0.000309629	0.00048
69	34.5	0.51	0.39	0.000309629	0.00048
70	35	0.51	0.39	0.000309629	0.00048
71	35.5	0.51	0.39	0.000309629	0.00048
72	36	0.5	0.38	0.00030169	0.00049
73	36.5	0.51	0.39	0.000309629	0.00048
74	37	0.5	0.38	0.00030169	0.00049
75	37.5	0.51	0.39	0.000309629	0.00048
76	38	0.51	0.39	0.000309629	0.00048
77	38.5	0.5	0.38	0.00030169	0.00049
78	39	0.5	0.38	0.00030169	0.00049
79	39.5	0.51	0.39	0.000309629	0.00048
80	40	0.51	0.39	0.000309629	0.00048
81	40.5	0.51	0.39	0.000309629	0.00048
82	41	0.51	0.39	0.000309629	0.00048
83	41.5	0.51	0.39	0.000309629	0.00048
84	42	0.51	0.39	0.000309629	0.00048
85	42.5	0.51	0.39	0.000309629	0.00048
86	43	0.51	0.39	0.000309629	0.00048
87	43.5	0.5	0.38	0.00030169	0.00049
88	44	0.5	0.38	0.00030169	0.00049
89	44.5	0.5	0.38	0.00030169	0.00049
90	45	0.5	0.38	0.00030169	0.00049
91	45.5	0.5	0.38	0.00030169	0.00049
92	46	0.5	0.38	0.00030169	0.00049
93	46.5	0.5	0.38	0.00030169	0.00049
94	47	0.5	0.38	0.00030169	0.00049
95	47.5	0.5	0.38	0.00030169	0.00049
96	48	0.5	0.38	0.00030169	0.00049
97	48.5	0.5	0.38	0.00030169	0.00049
98	49	0.5	0.38	0.00030169	0.00049
99	49.5	0.5	0.38	0.00030169	0.00049
100	50	0.5	0.38	0.00030169	0.00049

101	50.5	0.5	0.38	0.00030169	0.00049
102	51	0.5	0.38	0.00030169	0.00049
103	51.5	0.5	0.38	0.00030169	0.00049
104	52	0.5	0.38	0.00030169	0.00049
105	52.5	0.5	0.38	0.00030169	0.00049
106	53	0.5	0.38	0.00030169	0.00049
107	53.5	0.5	0.38	0.00030169	0.00049
108	54	0.5	0.38	0.00030169	0.00049
109	54.5	0.5	0.38	0.00030169	0.00049
110	55	0.5	0.38	0.00030169	0.00049
111	55.5	0.5	0.38	0.00030169	0.00049
112	56	0.5	0.38	0.00030169	0.00049
113	56.5	0.5	0.38	0.00030169	0.00049
114	57	0.5	0.38	0.00030169	0.00049
115	57.5	0.5	0.38	0.00030169	0.00049
116	58	0.5	0.38	0.00030169	0.00049
117	58.5	0.5	0.38	0.00030169	0.00049
118	59	0.5	0.38	0.00030169	0.00049
119	59.5	0.5	0.38	0.00030169	0.00049
120	60	0.5	0.38	0.00030169	0.00049

Type of Amine	Methyl Diethanolamine / Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	1 Bar

no	t(min)	P Total (bar)	P C02 (bar)	n C02	n C02 / n amine
1	0.5	1.1	1	0.000744762	0.00000
2	1	0.93	0.83	0.000618152	0.00013
3	1.5	0.89	0.79	0.000588362	0.00016
4	2	0.64	0.54	0.000402171	0.00034
5	2.5	0.65	0.55	0.000409619	0.00034
6	3	0.64	0.54	0.000402171	0.00034
7	3.5	0.65	0.55	0.000409619	0.00034
8	4	0.64	0.54	0.000402171	0.00034
9	4.5	0.64	0.54	0.000402171	0.00034
10	5	0.64	0.54	0.000402171	0.00034
11	5.5	0.64	0.54	0.000402171	0.00034
12	6	0.63	0.53	0.000394724	0.00035
13	6.5	0.64	0.54	0.000402171	0.00034
14	7	0.64	0.54	0.000402171	0.00034
15	7.5	0.63	0.53	0.000394724	0.00035
16	8	0.63	0.53	0.000394724	0.00035
17	8.5	0.63	0.53	0.000394724	0.00035

18	9	0.64	0.54	0.000402171	0.00034
19	9.5	0.63	0.53	0.000394724	0.00035
20	10	0.63	0.53	0.000394724	0.00035
21	10.5	0.64	0.54	0.000402171	0.00034
22	11	0.63	0.53	0.000394724	0.00035
23	11.5	0.63	0.53	0.000394724	0.00035
24	12	0.63	0.53	0.000394724	0.00035
25	12.5	0.63	0.53	0.000394724	0.00035
26	13	0.63	0.53	0.000394724	0.00035
27	13.5	0.64	0.54	0.000402171	0.00034
28	14	0.62	0.52	0.000387276	0.00036
29	14.5	0.63	0.53	0.000394724	0.00035
30	15	0.63	0.53	0.000394724	0.00035
31	15.5	0.63	0.53	0.000394724	0.00035
32	16	0.62	0.52	0.000387276	0.00036
33	16.5	0.63	0.53	0.000394724	0.00035
34	17	0.63	0.53	0.000394724	0.00035
35	17.5	0.63	0.53	0.000394724	0.00035
36	18	0.62	0.52	0.000387276	0.00036
37	18.5	0.63	0.53	0.000394724	0.00035
38	19	0.62	0.52	0.000387276	0.00036
39	19.5	0.63	0.53	0.000394724	0.00035
40	20	0.62	0.52	0.000387276	0.00036
41	20.5	0.61	0.51	0.000379829	0.00036
42	21	0.62	0.52	0.000387276	0.00036
43	21.5	0.63	0.53	0.000394724	0.00035
44	22	0.62	0.52	0.000387276	0.00036
45	22.5	0.62	0.52	0.000387276	0.00036
46	23	0.62	0.52	0.000387276	0.00036
47	23.5	0.61	0.51	0.000379829	0.00036
48	24	0.62	0.52	0.000387276	0.00036
49	24.5	0.63	0.53	0.000394724	0.00035
50	25	0.62	0.52	0.000387276	0.00036
51	25.5	0.62	0.52	0.000387276	0.00036
52	26	0.61	0.51	0.000379829	0.00036
53	26.5	0.62	0.52	0.000387276	0.00036
54	27	0.61	0.51	0.000379829	0.00036
55	27.5	0.61	0.51	0.000379829	0.00036
56	28	0.61	0.51	0.000379829	0.00036
57	28.5	0.62	0.52	0.000387276	0.00036
58	29	0.61	0.51	0.000379829	0.00036
59	29.5	0.62	0.52	0.000387276	0.00036
60	30	0.62	0.52	0.000387276	0.00036
61	30.5	0.61	0.51	0.000379829	0.00036
62	31	0.61	0.51	0.000379829	0.00036
63	31.5	0.62	0.52	0.000387276	0.00036
64	32	0.61	0.51	0.000379829	0.00036
65	32.5	0.61	0.51	0.000379829	0.00036
66	33	0.61	0.51	0.000379829	0.00036

67	33.5	0.61	0.51	0.000379829	0.00036
68	34	0.62	0.52	0.000387276	0.00036
69	34.5	0.6	0.5	0.000372381	0.00037
70	35	0.6	0.5	0.000372381	0.00037
71	35.5	0.6	0.5	0.000372381	0.00037
72	36	0.59	0.49	0.000364933	0.00038
73	36.5	0.6	0.5	0.000372381	0.00037
74	37	0.59	0.49	0.000364933	0.00038
75	37.5	0.59	0.49	0.000364933	0.00038
76	38	0.59	0.49	0.000364933	0.00038
77	38.5	0.59	0.49	0.000364933	0.00038
78	39	0.58	0.48	0.000357486	0.00039
79	39.5	0.59	0.49	0.000364933	0.00038
80	40	0.58	0.48	0.000357486	0.00039
81	40.5	0.58	0.48	0.000357486	0.00039
82	41	0.58	0.48	0.000357486	0.00039
83	41.5	0.58	0.48	0.000357486	0.00039
84	42	0.58	0.48	0.000357486	0.00039
85	42.5	0.58	0.48	0.000357486	0.00039
86	43	0.58	0.48	0.000357486	0.00039
87	43.5	0.58	0.48	0.000357486	0.00039
88	44	0.58	0.48	0.000357486	0.00039
89	44.5	0.58	0.48	0.000357486	0.00039
90	45	0.58	0.48	0.000357486	0.00039
91	45.5	0.58	0.48	0.000357486	0.00039
92	46	0.58	0.48	0.000357486	0.00039
93	46.5	0.58	0.48	0.000357486	0.00039
94	47	0.58	0.48	0.000357486	0.00039
95	47.5	0.58	0.48	0.000357486	0.00039
96	48	0.58	0.48	0.000357486	0.00039
97	48.5	0.58	0.48	0.000357486	0.00039
98	49	0.58	0.48	0.000357486	0.00039
99	49.5	0.58	0.48	0.000357486	0.00039
100	50	0.58	0.48	0.000357486	0.00039
101	50.5	0.58	0.48	0.000357486	0.00039
102	51	0.58	0.48	0.000357486	0.00039
103	51.5	0.58	0.48	0.000357486	0.00039
104	52	0.58	0.48	0.000357486	0.00039
105	52.5	0.58	0.48	0.000357486	0.00039
106	53	0.58	0.48	0.000357486	0.00039
107	53.5	0.58	0.48	0.000357486	0.00039
108	54	0.58	0.48	0.000357486	0.00039
109	54.5	0.58	0.48	0.000357486	0.00039
110	55	0.58	0.48	0.000357486	0.00039
111	55.5	0.58	0.48	0.000357486	0.00039
112	56	0.58	0.48	0.000357486	0.00039
113	56.5	0.58	0.48	0.000357486	0.00039
114	57	0.58	0.48	0.000357486	0.00039
115	57.5	0.58	0.48	0.000357486	0.00039

116	58	0.58	0.48	0.000357486	0.00039
117	58.5	0.58	0.48	0.000357486	0.00039
118	59	0.58	0.48	0.000357486	0.00039
119	59.5	0.58	0.48	0.000357486	0.00039
120	60	0.58	0.48	0.000357486	0.00039

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	3 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2	n CO_2 / n amine
1	0.5	3.18	3	0.002381763	0.00000
2	1	2.49	2.31	0.001833958	0.00055
3	1.5	2.34	2.16	0.00171487	0.00067
4	2	2.26	2.08	0.001651356	0.00073
5	2.5	2.18	2	0.001587842	0.00079
6	3	2.11	1.93	0.001532268	0.00085
7	3.5	2.04	1.86	0.001476693	0.00091
8	4	1.97	1.79	0.001421119	0.00096
9	4.5	1.91	1.73	0.001373484	0.00101
10	5	1.84	1.66	0.001317909	0.00106
11	5.5	1.79	1.61	0.001278213	0.00110
12	6	1.73	1.55	0.001230578	0.00115
13	6.5	1.67	1.49	0.001182942	0.00120
14	7	1.63	1.45	0.001151186	0.00123
15	7.5	1.58	1.4	0.00111149	0.00127
16	8	1.54	1.36	0.001079733	0.00130
17	8.5	1.51	1.33	0.001055915	0.00133
18	9	1.47	1.29	0.001024158	0.00136
19	9.5	1.43	1.25	0.000992401	0.00139
20	10	1.39	1.21	0.000960645	0.00142
21	10.5	1.34	1.16	0.000920948	0.00146
22	11	1.31	1.13	0.000897131	0.00148
23	11.5	1.28	1.1	0.000873313	0.00151
24	12	1.25	1.07	0.000849496	0.00153
25	12.5	1.21	1.03	0.000817739	0.00156
26	13	1.2	1.02	0.0008098	0.00157
27	13.5	1.17	0.99	0.000785982	0.00160
28	14	1.16	0.98	0.000778043	0.00160
29	14.5	1.12	0.94	0.000746286	0.00164
30	15	1.1	0.92	0.000730407	0.00165
31	15.5	1.08	0.9	0.000714529	0.00167
32	16	1.07	0.89	0.00070659	0.00168

FYP II FINAL REPORT

33	16.5	1.05	0.87	0.000690711	0.00169
34	17	1.05	0.87	0.000690711	0.00169
35	17.5	1.04	0.86	0.000682772	0.00170
36	18	1.03	0.85	0.000674833	0.00171
37	18.5	1.02	0.84	0.000666894	0.00171
38	19	1.03	0.85	0.000674833	0.00171
39	19.5	1.01	0.83	0.000658955	0.00172
40	20	1	0.82	0.000651015	0.00173
41	20.5	1.01	0.83	0.000658955	0.00172
42	21	1	0.82	0.000651015	0.00173
43	21.5	0.99	0.81	0.000643076	0.00174
44	22	1.01	0.83	0.000658955	0.00172
45	22.5	1	0.82	0.000651015	0.00173
46	23	1	0.82	0.000651015	0.00173
47	23.5	1	0.82	0.000651015	0.00173
48	24	1	0.82	0.000651015	0.00173
49	24.5	1	0.82	0.000651015	0.00173
50	25	0.99	0.81	0.000643076	0.00174
51	25.5	1	0.82	0.000651015	0.00173
52	26	0.99	0.81	0.000643076	0.00174
53	26.5	0.99	0.81	0.000643076	0.00174
54	27	0.99	0.81	0.000643076	0.00174
55	27.5	0.99	0.81	0.000643076	0.00174
56	28	0.98	0.8	0.000635137	0.00175
57	28.5	0.98	0.8	0.000635137	0.00175
58	29	0.99	0.81	0.000643076	0.00174
59	29.5	0.98	0.8	0.000635137	0.00175
60	30	0.98	0.8	0.000635137	0.00175
61	30.5	0.97	0.79	0.000627198	0.00175
62	31	0.98	0.8	0.000635137	0.00175
63	31.5	0.97	0.79	0.000627198	0.00175
64	32	0.98	0.8	0.000635137	0.00175
65	32.5	0.98	0.8	0.000635137	0.00175
66	33	0.98	0.8	0.000635137	0.00175
67	33.5	0.98	0.8	0.000635137	0.00175
68	34	0.97	0.79	0.000627198	0.00175
69	34.5	0.97	0.79	0.000627198	0.00175
70	35	0.97	0.79	0.000627198	0.00175
71	35.5	0.97	0.79	0.000627198	0.00175
72	36	0.97	0.79	0.000627198	0.00175
73	36.5	0.98	0.8	0.000635137	0.00175
74	37	0.96	0.78	0.000619258	0.00176
75	37.5	0.97	0.79	0.000627198	0.00175
76	38	0.97	0.79	0.000627198	0.00175
77	38.5	0.97	0.79	0.000627198	0.00175
78	39	0.97	0.79	0.000627198	0.00175
79	39.5	0.96	0.78	0.000619258	0.00176
80	40	0.97	0.79	0.000627198	0.00175

81	40.5	0.96	0.78	0.000619258	0.00176
82	41	0.96	0.78	0.000619258	0.00176
83	41.5	0.97	0.79	0.000627198	0.00175
84	42	0.96	0.78	0.000619258	0.00176
85	42.5	0.97	0.79	0.000627198	0.00175
86	43	0.96	0.78	0.000619258	0.00176
87	43.5	0.96	0.78	0.000619258	0.00176
88	44	0.96	0.78	0.000619258	0.00176
89	44.5	0.96	0.78	0.000619258	0.00176
90	45	0.96	0.78	0.000619258	0.00176
91	45.5	0.96	0.78	0.000619258	0.00176
92	46	0.96	0.78	0.000619258	0.00176
93	46.5	0.95	0.77	0.000611319	0.00177
94	47	0.96	0.78	0.000619258	0.00176
95	47.5	0.95	0.77	0.000611319	0.00177
96	48	0.96	0.78	0.000619258	0.00176
97	48.5	0.96	0.78	0.000619258	0.00176
98	49	0.97	0.79	0.000627198	0.00175
99	49.5	0.96	0.78	0.000619258	0.00176
100	50	0.96	0.78	0.000619258	0.00176
101	50.5	0.96	0.78	0.000619258	0.00176
102	51	0.95	0.77	0.000611319	0.00177
103	51.5	0.95	0.77	0.000611319	0.00177
104	52	0.95	0.77	0.000611319	0.00177
105	52.5	0.95	0.77	0.000611319	0.00177
106	53	0.95	0.77	0.000611319	0.00177
107	53.5	0.94	0.76	0.00060338	0.00178
108	54	0.95	0.77	0.000611319	0.00177
109	54.5	0.95	0.77	0.000611319	0.00177
110	55	0.95	0.77	0.000611319	0.00177
111	55.5	0.95	0.77	0.000611319	0.00177
112	56	0.95	0.77	0.000611319	0.00177
113	56.5	0.94	0.76	0.00060338	0.00178
114	57	0.95	0.77	0.000611319	0.00177
115	57.5	0.95	0.77	0.000611319	0.00177
116	58	0.94	0.76	0.00060338	0.00178
117	58.5	0.95	0.77	0.000611319	0.00177
118	59	0.94	0.76	0.00060338	0.00178
119	59.5	0.94	0.76	0.00060338	0.00178
120	60	0.94	0.76	0.00060338	0.00178
121	60.5	0.94	0.76	0.00060338	0.00178
122	61	0.94	0.76	0.00060338	0.00178
123	61.5	0.94	0.76	0.00060338	0.00178
124	62	0.96	0.78	0.000619258	0.00176
125	62.5	0.93	0.75	0.000595441	0.00179
126	63	0.93	0.75	0.000595441	0.00179
127	63.5	0.94	0.76	0.00060338	0.00178
128	64	0.95	0.77	0.000611319	0.00177

FYP II FINAL REPORT

129	64.5	0.93	0.75	0.000595441	0.00179
130	65	0.93	0.75	0.000595441	0.00179
131	65.5	0.94	0.76	0.00060338	0.00178
132	66	0.94	0.76	0.00060338	0.00178
133	66.5	0.94	0.76	0.00060338	0.00178
134	67	0.93	0.75	0.000595441	0.00179
135	67.5	0.93	0.75	0.000595441	0.00179
136	68	0.93	0.75	0.000595441	0.00179
137	68.5	0.93	0.75	0.000595441	0.00179
138	69	0.93	0.75	0.000595441	0.00179
139	69.5	0.93	0.75	0.000595441	0.00179
140	70	0.93	0.75	0.000595441	0.00179
141	70.5	0.93	0.75	0.000595441	0.00179
142	71	0.93	0.75	0.000595441	0.00179
143	71.5	0.93	0.75	0.000595441	0.00179
144	72	0.93	0.75	0.000595441	0.00179
145	72.5	0.93	0.75	0.000595441	0.00179
146	73	0.93	0.75	0.000595441	0.00179
147	73.5	0.93	0.75	0.000595441	0.00179
148	74	0.93	0.75	0.000595441	0.00179
149	74.5	0.93	0.75	0.000595441	0.00179
150	75	0.93	0.75	0.000595441	0.00179
151	75.5	0.93	0.75	0.000595441	0.00179
152	76	0.93	0.75	0.000595441	0.00179
153	76.5	0.93	0.75	0.000595441	0.00179
154	77	0.93	0.75	0.000595441	0.00179
155	77.5	0.93	0.75	0.000595441	0.00179
156	78	0.93	0.75	0.000595441	0.00179
157	78.5	0.93	0.75	0.000595441	0.00179
158	79	0.93	0.75	0.000595441	0.00179
159	79.5	0.93	0.75	0.000595441	0.00179
160	80	0.93	0.75	0.000595441	0.00179
161	80.5	0.93	0.75	0.000595441	0.00179
162	81	0.93	0.75	0.000595441	0.00179
163	81.5	0.93	0.75	0.000595441	0.00179
164	82	0.93	0.75	0.000595441	0.00179
165	82.5	0.93	0.75	0.000595441	0.00179
166	83	0.93	0.75	0.000595441	0.00179
167	83.5	0.93	0.75	0.000595441	0.00179
168	84	0.93	0.75	0.000595441	0.00179
169	84.5	0.93	0.75	0.000595441	0.00179
170	85	0.93	0.75	0.000595441	0.00179
171	85.5	0.93	0.75	0.000595441	0.00179
172	86	0.93	0.75	0.000595441	0.00179
173	86.5	0.93	0.75	0.000595441	0.00179
174	87	0.93	0.75	0.000595441	0.00179
175	87.5	0.93	0.75	0.000595441	0.00179
176	88	0.93	0.75	0.000595441	0.00179

177	88.5	0.93	0.75	0.000595441	0.00179
178	89	0.93	0.75	0.000595441	0.00179
179	89.5	0.93	0.75	0.000595441	0.00179
180	90	0.93	0.75	0.000595441	0.00179

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	3 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2	n CO_2 / n amine
1	0.5	3	3	0.002234286	0.00000
2	1	2.67	2.67	0.001988514	0.00025
3	1.5	2.21	2.21	0.001645924	0.00059
4	2	2.1	2.1	0.001564	0.00067
5	2.5	1.99	1.99	0.001482076	0.00075
6	3	1.87	1.87	0.001392705	0.00084
7	3.5	1.78	1.78	0.001325676	0.00091
8	4	1.7	1.7	0.001266095	0.00097
9	4.5	1.63	1.63	0.001213962	0.00102
10	5	1.57	1.57	0.001169276	0.00107
11	5.5	1.5	1.5	0.001117143	0.00112
12	6	1.46	1.46	0.001087352	0.00115
13	6.5	1.42	1.42	0.001057562	0.00118
14	7	1.39	1.39	0.001035219	0.00120
15	7.5	1.36	1.36	0.001012876	0.00122
16	8	1.33	1.33	0.000990533	0.00124
17	8.5	1.32	1.32	0.000983086	0.00125
18	9	1.3	1.3	0.00096819	0.00127
19	9.5	1.29	1.29	0.000960743	0.00127
20	10	1.3	1.3	0.00096819	0.00127
21	10.5	1.29	1.29	0.000960743	0.00127
22	11	1.29	1.29	0.000960743	0.00127
23	11.5	1.28	1.28	0.000953295	0.00128
24	12	1.28	1.28	0.000953295	0.00128
25	12.5	1.28	1.28	0.000953295	0.00128
26	13	1.28	1.28	0.000953295	0.00128
27	13.5	1.28	1.28	0.000953295	0.00128
28	14	1.27	1.27	0.000945848	0.00129
29	14.5	1.27	1.27	0.000945848	0.00129
30	15	1.27	1.27	0.000945848	0.00129
31	15.5	1.26	1.26	0.0009384	0.00130
32	16	1.25	1.25	0.000930952	0.00130

FYP II FINAL REPORT

33	16.5	1.26	1.26	0.0009384	0.00130
34	17	1.26	1.26	0.0009384	0.00130
35	17.5	1.26	1.26	0.0009384	0.00130
36	18	1.26	1.26	0.0009384	0.00130
37	18.5	1.26	1.26	0.0009384	0.00130
38	19	1.26	1.26	0.0009384	0.00130
39	19.5	1.25	1.25	0.000930952	0.00130
40	20	1.26	1.26	0.0009384	0.00130
41	20.5	1.26	1.26	0.0009384	0.00130
42	21	1.25	1.25	0.000930952	0.00130
43	21.5	1.25	1.25	0.000930952	0.00130
44	22	1.25	1.25	0.000930952	0.00130
45	22.5	1.25	1.25	0.000930952	0.00130
46	23	1.25	1.25	0.000930952	0.00130
47	23.5	1.25	1.25	0.000930952	0.00130
48	24	1.25	1.25	0.000930952	0.00130
49	24.5	1.25	1.25	0.000930952	0.00130
50	25	1.24	1.24	0.000923505	0.00131
51	25.5	1.25	1.25	0.000930952	0.00130
52	26	1.24	1.24	0.000923505	0.00131
53	26.5	1.24	1.24	0.000923505	0.00131
54	27	1.23	1.23	0.000916057	0.00132
55	27.5	1.23	1.23	0.000916057	0.00132
56	28	1.24	1.24	0.000923505	0.00131
57	28.5	1.23	1.23	0.000916057	0.00132
58	29	1.24	1.24	0.000923505	0.00131
59	29.5	1.24	1.24	0.000923505	0.00131
60	30	1.24	1.24	0.000923505	0.00131
61	30.5	1.23	1.23	0.000916057	0.00132
62	31	1.23	1.23	0.000916057	0.00132
63	31.5	1.23	1.23	0.000916057	0.00132
64	32	1.23	1.23	0.000916057	0.00132
65	32.5	1.23	1.23	0.000916057	0.00132
66	33	1.22	1.22	0.00090861	0.00133
67	33.5	1.22	1.22	0.00090861	0.00133
68	34	1.23	1.23	0.000916057	0.00132
69	34.5	1.23	1.23	0.000916057	0.00132
70	35	1.22	1.22	0.00090861	0.00133
71	35.5	1.22	1.22	0.00090861	0.00133
72	36	1.23	1.23	0.000916057	0.00132
73	36.5	1.23	1.23	0.000916057	0.00132
74	37	1.23	1.23	0.000916057	0.00132
75	37.5	1.22	1.22	0.00090861	0.00133
76	38	1.21	1.21	0.000901162	0.00133
77	38.5	1.23	1.23	0.000916057	0.00132
78	39	1.22	1.22	0.00090861	0.00133
79	39.5	1.22	1.22	0.00090861	0.00133
80	40	1.22	1.22	0.00090861	0.00133

FYP II FINAL REPORT

81	40.5	1.22	1.22	0.00090861	0.00133
82	41	1.22	1.22	0.00090861	0.00133
83	41.5	1.22	1.22	0.00090861	0.00133
84	42	1.22	1.22	0.00090861	0.00133
85	42.5	1.21	1.21	0.000901162	0.00133
86	43	1.21	1.21	0.000901162	0.00133
87	43.5	1.21	1.21	0.000901162	0.00133
88	44	1.21	1.21	0.000901162	0.00133
89	44.5	1.21	1.21	0.000901162	0.00133
90	45	1.22	1.22	0.00090861	0.00133
91	45.5	1.22	1.22	0.00090861	0.00133
92	46	1.22	1.22	0.00090861	0.00133
93	46.5	1.22	1.22	0.00090861	0.00133
94	47	1.21	1.21	0.000901162	0.00133
95	47.5	1.22	1.22	0.00090861	0.00133
96	48	1.21	1.21	0.000901162	0.00133
97	48.5	1.21	1.21	0.000901162	0.00133
98	49	1.22	1.22	0.00090861	0.00133
99	49.5	1.21	1.21	0.000901162	0.00133
100	50	1.21	1.21	0.000901162	0.00133
101	50.5	1.21	1.21	0.000901162	0.00133
102	51	1.21	1.21	0.000901162	0.00133
103	51.5	1.21	1.21	0.000901162	0.00133
104	52	1.21	1.21	0.000901162	0.00133
105	52.5	1.2	1.2	0.000893714	0.00134
106	53	1.22	1.22	0.00090861	0.00133
107	53.5	1.21	1.21	0.000901162	0.00133
108	54	1.21	1.21	0.000901162	0.00133
109	54.5	1.21	1.21	0.000901162	0.00133
110	55	1.2	1.2	0.000893714	0.00134
111	55.5	1.21	1.21	0.000901162	0.00133
112	56	1.2	1.2	0.000893714	0.00134
113	56.5	1.21	1.21	0.000901162	0.00133
114	57	1.21	1.21	0.000901162	0.00133
115	57.5	1.21	1.21	0.000901162	0.00133
116	58	1.21	1.21	0.000901162	0.00133
117	58.5	1.21	1.21	0.000901162	0.00133
118	59	1.2	1.2	0.000893714	0.00134
119	59.5	1.2	1.2	0.000893714	0.00134
120	60	1.2	1.2	0.000893714	0.00134
121	60.5	1.2	1.2	0.000893714	0.00134
122	61	1.2	1.2	0.000893714	0.00134
123	61.5	1.2	1.2	0.000893714	0.00134
124	62	1.2	1.2	0.000893714	0.00134
125	62.5	1.2	1.2	0.000893714	0.00134
126	63	1.2	1.2	0.000893714	0.00134
127	63.5	1.2	1.2	0.000893714	0.00134
128	64	1.2	1.2	0.000893714	0.00134
129	64.5	1.2	1.2	0.000893714	0.00134
130	65	1.2	1.2	0.000893714	0.00134
131	65.5	1.2	1.2	0.000893714	0.00134
132	66	1.2	1.2	0.000893714	0.00134
133	66.5	1.2	1.2	0.000893714	0.00134
134	67	1.2	1.2	0.000893714	0.00134
135	67.5	1.2	1.2	0.000893714	0.00134
136	68	1.2	1.2	0.000893714	0.00134
137	68.5	1.2	1.2	0.000893714	0.00134
138	69	1.2	1.2	0.000893714	0.00134
139	69.5	1.2	1.2	0.000893714	0.00134
140	70	1.2	1.2	0.000893714	0.00134
141	70.5	1.2	1.2	0.000893714	0.00134
142	71	1.2	1.2	0.000893714	0.00134
143	71.5	1.2	1.2	0.000893714	0.00134
144	72	1.2	1.2	0.000893714	0.00134
145	72.5	1.2	1.2	0.000893714	0.00134
146	73	1.2	1.2	0.000893714	0.00134
147	73.5	1.2	1.2	0.000893714	0.00134
148	74	1.2	1.2	0.000893714	0.00134
149	74.5	1.2	1.2	0.000893714	0.00134
150	75	1.2	1.2	0.000893714	0.00134
151	75.5	1.2	1.2	0.000893714	0.00134
152	76	1.2	1.2	0.000893714	0.00134
153	76.5	1.2	1.2	0.000893714	0.00134
154	77	1.2	1.2	0.000893714	0.00134
155	77.5	1.2	1.2	0.000893714	0.00134
156	78	1.2	1.2	0.000893714	0.00134
157	78.5	1.2	1.2	0.000893714	0.00134
158	79	1.2	1.2	0.000893714	0.00134
159	79.5	1.2	1.2	0.000893714	0.00134
160	80	1.2	1.2	0.000893714	0.00134
161	80.5	1.2	1.2	0.000893714	0.00134
162	81	1.2	1.2	0.000893714	0.00134
163	81.5	1.2	1.2	0.000893714	0.00134
164	82	1.2	1.2	0.000893714	0.00134
165	82.5	1.2	1.2	0.000893714	0.00134
166	83	1.2	1.2	0.000893714	0.00134
167	83.5	1.2	1.2	0.000893714	0.00134
168	84	1.2	1.2	0.000893714	0.00134
169	84.5	1.2	1.2	0.000893714	0.00134
170	85	1.2	1.2	0.000893714	0.00134
171	85.5	1.2	1.2	0.000893714	0.00134
172	86	1.2	1.2	0.000893714	0.00134
173	86.5	1.2	1.2	0.000893714	0.00134
174	87	1.2	1.2	0.000893714	0.00134
175	87.5	1.2	1.2	0.000893714	0.00134
176	88	1.2	1.2	0.000893714	0.00134

177	88.5	1.2	1.2	0.000893714	0.00134
178	89	1.2	1.2	0.000893714	0.00134
179	89.5	1.2	1.2	0.000893714	0.00134
180	90	1.2	1.2	0.000893714	0.00134

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	30
Pressure (bar)	3 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2	n CO_2 / n amine
1	0.5	3.06	3	0.002381763	0.00000
2	1	2.95	2.89	0.002294432	0.00009
3	1.5	2.84	2.78	0.002207101	0.00017
4	2	2.73	2.67	0.002119769	0.00026
5	2.5	2.61	2.55	0.002024499	0.00036
6	3	2.5	2.44	0.001937167	0.00044
7	3.5	2.38	2.32	0.001841897	0.00054
8	4	2.29	2.23	0.001770444	0.00061
9	4.5	2.2	2.14	0.001698991	0.00068
10	5	2.11	2.05	0.001627538	0.00075
11	5.5	2.03	1.97	0.001564025	0.00082
12	6	1.93	1.87	0.001484632	0.00090
13	6.5	1.84	1.78	0.00141318	0.00097
14	7	1.75	1.69	0.001341727	0.00104
15	7.5	1.67	1.61	0.001278213	0.00110
16	8	1.6	1.54	0.001222639	0.00116
17	8.5	1.53	1.47	0.001167064	0.00121
18	9	1.46	1.4	0.00111149	0.00127
19	9.5	1.4	1.34	0.001063854	0.00132
20	10	1.34	1.28	0.001016219	0.00137
21	10.5	1.27	1.21	0.000960645	0.00142
22	11	1.22	1.16	0.000920948	0.00146
23	11.5	1.16	1.1	0.000873313	0.00151
24	12	1.12	1.06	0.000841556	0.00154
25	12.5	1.07	1.01	0.00080186	0.00158
26	13	1.02	0.96	0.000762164	0.00162
27	13.5	0.99	0.93	0.000738347	0.00164
28	14	0.98	0.92	0.000730407	0.00165
29	14.5	0.96	0.9	0.000714529	0.00167
30	15	0.95	0.89	0.00070659	0.00168
31	15.5	0.94	0.88	0.000698651	0.00168
32	16	0.94	0.88	0.000698651	0.00168
33	16.5	0.94	0.88	0.000698651	0.00168
34	17	0.94	0.88	0.000698651	0.00168

FYP II FINAL REPORT

35	17.5	0.93	0.87	0.000690711	0.00169
36	18	0.92	0.86	0.000682772	0.00170
37	18.5	0.94	0.88	0.000698651	0.00168
38	19	0.93	0.87	0.000690711	0.00169
39	19.5	0.92	0.86	0.000682772	0.00170
40	20	0.93	0.87	0.000690711	0.00169
41	20.5	0.93	0.87	0.000690711	0.00169
42	21	0.92	0.86	0.000682772	0.00170
43	21.5	0.92	0.86	0.000682772	0.00170
44	22	0.92	0.86	0.000682772	0.00170
45	22.5	0.93	0.87	0.000690711	0.00169
46	23	0.93	0.87	0.000690711	0.00169
47	23.5	0.92	0.86	0.000682772	0.00170
48	24	0.93	0.87	0.000690711	0.00169
49	24.5	0.93	0.87	0.000690711	0.00169
50	25	0.93	0.87	0.000690711	0.00169
51	25.5	0.92	0.86	0.000682772	0.00170
52	26	0.92	0.86	0.000682772	0.00170
53	26.5	0.92	0.86	0.000682772	0.00170
54	27	0.93	0.87	0.000690711	0.00169
55	27.5	0.92	0.86	0.000682772	0.00170
56	28	0.92	0.86	0.000682772	0.00170
57	28.5	0.92	0.86	0.000682772	0.00170
58	29	0.91	0.85	0.000674833	0.00171
59	29.5	0.92	0.86	0.000682772	0.00170
60	30	0.91	0.85	0.000674833	0.00171
61	30.5	0.91	0.85	0.000674833	0.00171
62	31	0.91	0.85	0.000674833	0.00171
63	31.5	0.91	0.85	0.000674833	0.00171
64	32	0.91	0.85	0.000674833	0.00171
65	32.5	0.91	0.85	0.000674833	0.00171
66	33	0.91	0.85	0.000674833	0.00171
67	33.5	0.92	0.86	0.000682772	0.00170
68	34	0.91	0.85	0.000674833	0.00171
69	34.5	0.9	0.84	0.000666894	0.00171
70	35	0.91	0.85	0.000674833	0.00171
71	35.5	0.92	0.86	0.000682772	0.00170
72	36	0.9	0.84	0.000666894	0.00171
73	36.5	0.91	0.85	0.000674833	0.00171
74	37	0.9	0.84	0.000666894	0.00171
75	37.5	0.9	0.84	0.000666894	0.00171
76	38	0.9	0.84	0.000666894	0.00171
77	38.5	0.9	0.84	0.000666894	0.00171
78	39	0.91	0.85	0.000674833	0.00171
79	39.5	0.9	0.84	0.000666894	0.00171
80	40	0.9	0.84	0.000666894	0.00171
81	40.5	0.9	0.84	0.000666894	0.00171
82	41	0.9	0.84	0.000666894	0.00171
83	41.5	0.9	0.84	0.000666894	0.00171

84	42	0.9	0.84	0.000666894	0.00171
85	42.5	0.9	0.84	0.000666894	0.00171
86	43	0.9	0.84	0.000666894	0.00171
87	43.5	0.9	0.84	0.000666894	0.00171
88	44	0.9	0.84	0.000666894	0.00171
89	44.5	0.9	0.84	0.000666894	0.00171
90	45	0.91	0.85	0.000674833	0.00171
91	45.5	0.9	0.84	0.000666894	0.00171
92	46	0.9	0.84	0.000666894	0.00171
93	46.5	0.89	0.83	0.000658955	0.00172
94	47	0.89	0.83	0.000658955	0.00172
95	47.5	0.89	0.83	0.000658955	0.00172
96	48	0.9	0.84	0.000666894	0.00171
97	48.5	0.89	0.83	0.000658955	0.00172
98	49	0.89	0.83	0.000658955	0.00172
99	49.5	0.89	0.83	0.000658955	0.00172
100	50	0.9	0.84	0.000666894	0.00171
101	50.5	0.89	0.83	0.000658955	0.00172
102	51	0.9	0.84	0.000666894	0.00171
103	51.5	0.89	0.83	0.000658955	0.00172
104	52	0.88	0.82	0.000651015	0.00173
105	52.5	0.89	0.83	0.000658955	0.00172
106	53	0.89	0.83	0.000658955	0.00172
107	53.5	0.89	0.83	0.000658955	0.00172
108	54	0.89	0.83	0.000658955	0.00172
109	54.5	0.9	0.84	0.000666894	0.00171
110	55	0.89	0.83	0.000658955	0.00172
111	55.5	0.89	0.83	0.000658955	0.00172
112	56	0.88	0.82	0.000651015	0.00173
113	56.5	0.88	0.82	0.000651015	0.00173
114	57	0.89	0.83	0.000658955	0.00172
115	57.5	0.89	0.83	0.000658955	0.00172
116	58	0.89	0.83	0.000658955	0.00172
117	58.5	0.88	0.82	0.000651015	0.00173
118	59	0.88	0.82	0.000651015	0.00173
119	59.5	0.88	0.82	0.000651015	0.00173
120	60	0.89	0.83	0.000658955	0.00172
121	60.5	0.88	0.82	0.000651015	0.00173
122	61	0.88	0.82	0.000651015	0.00173
123	61.5	0.88	0.82	0.000651015	0.00173
124	62	0.88	0.82	0.000651015	0.00173
125	62.5	0.88	0.82	0.000651015	0.00173
126	63	0.88	0.82	0.000651015	0.00173
127	63.5	0.88	0.82	0.000651015	0.00173
128	64	0.88	0.82	0.000651015	0.00173
129	64.5	0.88	0.82	0.000651015	0.00173
130	65	0.88	0.82	0.000651015	0.00173
131	65.5	0.87	0.81	0.000643076	0.00174
132	66	0.88	0.82	0.000651015	0.00173

FYP II FINAL REPORT

133	66.5	0.88	0.8	0.000635137	0.00175
134	67	0.89	0.78	0.000619258	0.00176
135	67.5	0.88	0.77	0.000611319	0.00177
136	68	0.88	0.77	0.000611319	0.00177
137	68.5	0.88	0.77	0.000611319	0.00177
138	69	0.87	0.77	0.000611319	0.00177
139	69.5	0.88	0.77	0.000611319	0.00177
140	70	0.88	0.77	0.000611319	0.00177
141	70.5	0.87	0.77	0.000611319	0.00177
142	71	0.88	0.77	0.000611319	0.00177
143	71.5	0.87	0.77	0.000611319	0.00177
144	72	0.88	0.77	0.000611319	0.00177
145	72.5	0.88	0.76	0.00060338	0.00178
146	73	0.88	0.75	0.000595441	0.00179
147	73.5	0.87	0.75	0.000595441	0.00179
148	74	0.87	0.74	0.000587502	0.00179
149	74.5	0.88	0.72	0.000571623	0.00181
150	75	0.87	0.7	0.000555745	0.00183
151	75.5	0.87	0.7	0.000555745	0.00183
152	76	0.87	0.7	0.000555745	0.00183
153	76.5	0.87	0.7	0.000555745	0.00183
154	77	0.87	0.7	0.000555745	0.00183
155	77.5	0.87	0.7	0.000555745	0.00183
156	78	0.88	0.7	0.000555745	0.00183
157	78.5	0.87	0.7	0.000555745	0.00183
158	79	0.88	0.7	0.000555745	0.00183
159	79.5	0.87	0.7	0.000555745	0.00183
160	80	0.87	0.7	0.000555745	0.00183
161	80.5	0.87	0.7	0.000555745	0.00183
162	81	0.87	0.7	0.000555745	0.00183
163	81.5	0.87	0.7	0.000555745	0.00183
164	82	0.87	0.7	0.000555745	0.00183
165	82.5	0.87	0.7	0.000555745	0.00183
166	83	0.87	0.7	0.000555745	0.00183
167	83.5	0.87	0.7	0.000555745	0.00183
168	84	0.87	0.7	0.000555745	0.00183
169	84.5	0.87	0.7	0.000555745	0.00183
170	85	0.87	0.7	0.000555745	0.00183
171	85.5	0.87	0.7	0.000555745	0.00183
172	86	0.87	0.7	0.000555745	0.00183
173	86.5	0.87	0.7	0.000555745	0.00183
174	87	0.87	0.7	0.000555745	0.00183
175	87.5	0.87	0.7	0.000555745	0.00183
176	88	0.87	0.7	0.000555745	0.00183
177	88.5	0.87	0.7	0.000555745	0.00183
178	89	0.87	0.7	0.000555745	0.00183
179	89.5	0.87	0.7	0.000555745	0.00183
180	90	0.87	0.7	0.000555745	0.00183

FYP II FINAL REPORT

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002
Temperature (°C)	50
Pressure (bar)	3 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2	n CO_2 / n amine
1	0.5	3.01	3	0.002234286	0.00000
2	1	2.44	2.43	0.001809771	0.00042
3	1.5	2.93	2.92	0.002174705	0.00006
4	2	2.95	2.94	0.0021896	0.00004
5	2.5	1.71	1.7	0.001266095	0.00097
6	3	1.42	1.41	0.001050114	0.00118
7	3.5	1.42	1.41	0.001050114	0.00118
8	4	1.42	1.41	0.001050114	0.00118
9	4.5	1.42	1.41	0.001050114	0.00118
10	5	1.42	1.41	0.001050114	0.00118
11	5.5	1.42	1.41	0.001050114	0.00118
12	6	1.4	1.39	0.001035219	0.00120
13	6.5	1.38	1.37	0.001020324	0.00121
14	7	1.38	1.37	0.001020324	0.00121
15	7.5	1.37	1.36	0.001012876	0.00122
16	8	1.36	1.35	0.001005429	0.00123
17	8.5	1.33	1.32	0.000983086	0.00125
18	9	1.31	1.3	0.00096819	0.00127
19	9.5	1.28	1.27	0.000945848	0.00129
20	10	1.28	1.27	0.000945848	0.00129
21	10.5	1.28	1.27	0.000945848	0.00129
22	11	1.28	1.27	0.000945848	0.00129
23	11.5	1.28	1.27	0.000945848	0.00129
24	12	1.28	1.27	0.000945848	0.00129
25	12.5	1.28	1.27	0.000945848	0.00129
26	13	1.28	1.27	0.000945848	0.00129
27	13.5	1.27	1.26	0.0009384	0.00130
28	14	1.26	1.25	0.000930952	0.00130
29	14.5	1.25	1.24	0.000923505	0.00131
30	15	1.24	1.23	0.000916057	0.00132
31	15.5	1.25	1.24	0.000923505	0.00131
32	16	1.25	1.24	0.000923505	0.00131
33	16.5	1.25	1.24	0.000923505	0.00131
34	17	1.25	1.24	0.000923505	0.00131
35	17.5	1.22	1.21	0.000901162	0.00133
36	18	1.22	1.21	0.000901162	0.00133
37	18.5	1.2	1.19	0.000886267	0.00135
38	19	1.21	1.2	0.000893714	0.00134
39	19.5	1.19	1.18	0.000878819	0.00136
40	20	1.18	1.17	0.000871371	0.00136
41	20.5	1.18	1.17	0.000871371	0.00136
42	21	1.18	1.17	0.000871371	0.00136
43	21.5	1.18	1.17	0.000871371	0.00136
44	22	1.18	1.17	0.000871371	0.00136
45	22.5	1.18	1.17	0.000871371	0.00136
46	23	1.18	1.17	0.000871371	0.00136
47	23.5	1.18	1.17	0.000871371	0.00136
48	24	1.18	1.17	0.000871371	0.00136
49	24.5	1.18	1.17	0.000871371	0.00136
50	25	1.18	1.17	0.000871371	0.00136
51	25.5	1.18	1.17	0.000871371	0.00136
52	26	1.18	1.17	0.000871371	0.00136
53	26.5	1.18	1.17	0.000871371	0.00136
54	27	1.18	1.17	0.000871371	0.00136
55	27.5	1.18	1.17	0.000871371	0.00136
56	28	1.18	1.17	0.000871371	0.00136
57	28.5	1.18	1.17	0.000871371	0.00136
58	29	1.19	1.18	0.000878819	0.00136
59	29.5	1.17	1.16	0.000863924	0.00137
60	30	1.17	1.16	0.000863924	0.00137
61	30.5	1.17	1.16	0.000863924	0.00137
62	31	1.17	1.16	0.000863924	0.00137
63	31.5	1.17	1.16	0.000863924	0.00137
64	32	1.17	1.16	0.000863924	0.00137
65	32.5	1.17	1.16	0.000863924	0.00137
66	33	1.18	1.17	0.000871371	0.00136
67	33.5	1.17	1.16	0.000863924	0.00137
68	34	1.17	1.16	0.000863924	0.00137
69	34.5	1.16	1.15	0.000856476	0.00138
70	35	1.16	1.15	0.000856476	0.00138
71	35.5	1.16	1.15	0.000856476	0.00138
72	36	1.16	1.15	0.000856476	0.00138
73	36.5	1.15	1.14	0.000849029	0.00139
74	37	1.15	1.14	0.000849029	0.00139
75	37.5	1.15	1.14	0.000849029	0.00139
76	38	1.15	1.14	0.000849029	0.00139
77	38.5	1.15	1.14	0.000849029	0.00139
78	39	1.15	1.14	0.000849029	0.00139
79	39.5	1.15	1.14	0.000849029	0.00139
80	40	1.14	1.13	0.000841581	0.00139
81	40.5	1.14	1.13	0.000841581	0.00139
82	41	1.14	1.13	0.000841581	0.00139
83	41.5	1.14	1.13	0.000841581	0.00139
84	42	1.14	1.13	0.000841581	0.00139
85	42.5	1.14	1.13	0.000841581	0.00139
86	43	1.14	1.13	0.000841581	0.00139
87	43.5	1.14	1.13	0.000841581	0.00139
88	44	1.14	1.13	0.000841581	0.00139
89	44.5	1.14	1.13	0.000841581	0.00139

90	45	1.14	1.13	0.000841581	0.00139
91	45.5	1.14	1.13	0.000841581	0.00139
92	46	1.14	1.13	0.000841581	0.00139
93	46.5	1.14	1.13	0.000841581	0.00139
94	47	1.14	1.13	0.000841581	0.00139
95	47.5	1.14	1.13	0.000841581	0.00139
96	48	1.14	1.13	0.000841581	0.00139
97	48.5	1.14	1.13	0.000841581	0.00139
98	49	1.14	1.13	0.000841581	0.00139
99	49.5	1.14	1.13	0.000841581	0.00139
100	50	1.14	1.13	0.000841581	0.00139
101	50.5	1.14	1.13	0.000841581	0.00139
102	51	1.14	1.13	0.000841581	0.00139
103	51.5	1.14	1.13	0.000841581	0.00139
104	52	1.14	1.13	0.000841581	0.00139
105	52.5	1.14	1.13	0.000841581	0.00139
106	53	1.14	1.13	0.000841581	0.00139
107	53.5	1.14	1.13	0.000841581	0.00139
108	54	1.14	1.13	0.000841581	0.00139
109	54.5	1.14	1.13	0.000841581	0.00139
110	55	1.14	1.13	0.000841581	0.00139
111	55.5	1.14	1.13	0.000841581	0.00139
112	56	1.14	1.13	0.000841581	0.00139
113	56.5	1.14	1.13	0.000841581	0.00139
114	57	1.14	1.13	0.000841581	0.00139
115	57.5	1.14	1.13	0.000841581	0.00139
116	58	1.14	1.13	0.000841581	0.00139
117	58.5	1.14	1.13	0.000841581	0.00139
118	59	1.14	1.13	0.000841581	0.00139
119	59.5	1.14	1.13	0.000841581	0.00139
120	60	1.14	1.13	0.000841581	0.00139
121	60.5	1.14	1.13	0.000841581	0.00139
122	61	1.14	1.13	0.000841581	0.00139
123	61.5	1.14	1.13	0.000841581	0.00139
124	62	1.14	1.13	0.000841581	0.00139
125	62.5	1.14	1.13	0.000841581	0.00139
126	63	1.14	1.13	0.000841581	0.00139
127	63.5	1.14	1.13	0.000841581	0.00139
128	64	1.14	1.13	0.000841581	0.00139
129	64.5	1.14	1.13	0.000841581	0.00139
130	65	1.14	1.13	0.000841581	0.00139
131	65.5	1.14	1.13	0.000841581	0.00139
132	66	1.14	1.13	0.000841581	0.00139
133	66.5	1.14	1.13	0.000841581	0.00139
134	67	1.14	1.13	0.000841581	0.00139
135	67.5	1.14	1.13	0.000841581	0.00139
136	68	1.14	1.13	0.000841581	0.00139
137	68.5	1.14	1.13	0.000841581	0.00139
138	69	1.14	1.13	0.000841581	0.00139

FYP II FINAL REPORT

139	69.5	1.14	1.13	0.000841581	0.00139
140	70	1.14	1.13	0.000841581	0.00139
141	70.5	1.14	1.13	0.000841581	0.00139
142	71	1.14	1.13	0.000841581	0.00139
143	71.5	1.14	1.13	0.000841581	0.00139
144	72	1.14	1.13	0.000841581	0.00139
145	72.5	1.14	1.13	0.000841581	0.00139
146	73	1.14	1.13	0.000841581	0.00139
147	73.5	1.14	1.13	0.000841581	0.00139
148	74	1.14	1.13	0.000841581	0.00139
149	74.5	1.14	1.13	0.000841581	0.00139
150	75	1.14	1.13	0.000841581	0.00139
151	75.5	1.14	1.13	0.000841581	0.00139
152	76	1.14	1.13	0.000841581	0.00139
153	76.5	1.14	1.13	0.000841581	0.00139
154	77	1.14	1.13	0.000841581	0.00139
155	77.5	1.14	1.13	0.000841581	0.00139
156	78	1.14	1.13	0.000841581	0.00139
157	78.5	1.14	1.13	0.000841581	0.00139
158	79	1.14	1.13	0.000841581	0.00139
159	79.5	1.14	1.13	0.000841581	0.00139
160	80	1.14	1.13	0.000841581	0.00139
161	80.5	1.14	1.13	0.000841581	0.00139
162	81	1.14	1.13	0.000841581	0.00139
163	81.5	1.14	1.13	0.000841581	0.00139
164	82	1.14	1.13	0.000841581	0.00139
165	82.5	1.14	1.13	0.000841581	0.00139
166	83	1.14	1.13	0.000841581	0.00139
167	83.5	1.14	1.13	0.000841581	0.00139
168	84	1.14	1.13	0.000841581	0.00139
169	84.5	1.14	1.13	0.000841581	0.00139
170	85	1.14	1.13	0.000841581	0.00139
171	85.5	1.14	1.13	0.000841581	0.00139
172	86	1.14	1.13	0.000841581	0.00139
173	86.5	1.14	1.13	0.000841581	0.00139
174	87	1.14	1.13	0.000841581	0.00139
175	87.5	1.14	1.13	0.000841581	0.00139
176	88	1.14	1.13	0.000841581	0.00139
177	88.5	1.14	1.13	0.000841581	0.00139
178	89	1.14	1.13	0.000841581	0.00139
179	89.5	1.14	1.13	0.000841581	0.00139
180	90	1.14	1.13	0.000841581	0.00139

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	30

Temperature (°C) 50
Pressure (bar) 5 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2	n CO_2 / n amine
1	0.5	5.14	5	0.00372381	0.00000
2	1	4.4	4.26	0.003172686	0.00055
3	1.5	4.09	3.95	0.00294181	0.00078
4	2	3.99	3.85	0.002867333	0.00086
5	2.5	3.81	3.67	0.002733276	0.00099
6	3	3.69	3.55	0.002643905	0.00108
7	3.5	3.55	3.41	0.002539638	0.00118
8	4	3.43	3.29	0.002450267	0.00127
9	4.5	3.32	3.18	0.002368343	0.00136
10	5	3.22	3.08	0.002293867	0.00143
11	5.5	3.13	2.99	0.002226838	0.00150
12	6	3.04	2.9	0.00215981	0.00156
13	6.5	2.96	2.82	0.002100229	0.00162
14	7	2.89	2.75	0.002048095	0.00168
15	7.5	2.79	2.65	0.001973619	0.00175
16	8	2.73	2.59	0.001928933	0.00179
17	8.5	2.65	2.51	0.001869352	0.00185
18	9	2.57	2.43	0.001809771	0.00191
19	9.5	2.49	2.35	0.00175019	0.00197
20	10	2.42	2.28	0.001698057	0.00203
21	10.5	2.37	2.23	0.001660819	0.00206
22	11	2.32	2.18	0.001623581	0.00210
23	11.5	2.28	2.14	0.00159379	0.00213
24	12	2.23	2.09	0.001556552	0.00217
25	12.5	2.2	2.06	0.00153421	0.00219
26	13	2.17	2.03	0.001511867	0.00221
27	13.5	2.14	2	0.001489524	0.00223
28	14	2.11	1.97	0.001467181	0.00226
29	14.5	2.1	1.96	0.001459733	0.00226
30	15	2.09	1.95	0.001452286	0.00227
31	15.5	2.07	1.93	0.00143739	0.00229
32	16	2.05	1.91	0.001422495	0.00230
33	16.5	2.04	1.9	0.001415048	0.00231
34	17	2.04	1.9	0.001415048	0.00231
35	17.5	2.03	1.89	0.0014076	0.00232
36	18	2.02	1.88	0.001400152	0.00232
37	18.5	2.01	1.87	0.001392705	0.00233
38	19	2	1.86	0.001385257	0.00234
39	19.5	2.01	1.87	0.001392705	0.00233
40	20	2	1.86	0.001385257	0.00234
41	20.5	2	1.86	0.001385257	0.00234
42	21	1.98	1.84	0.001370362	0.00235
43	21.5	1.98	1.84	0.001370362	0.00235
44	22	1.98	1.84	0.001370362	0.00235
45	22.5	1.98	1.84	0.001370362	0.00235
46	23	1.98	1.84	0.001370362	0.00235
47	23.5	1.97	1.83	0.001362914	0.00236
48	24	1.97	1.83	0.001362914	0.00236
49	24.5	1.96	1.82	0.001355467	0.00237
50	25	1.97	1.83	0.001362914	0.00236
51	25.5	1.96	1.82	0.001355467	0.00237
52	26	1.96	1.82	0.001355467	0.00237
53	26.5	1.97	1.83	0.001362914	0.00236
54	27	1.96	1.82	0.001355467	0.00237
55	27.5	1.96	1.82	0.001355467	0.00237
56	28	1.95	1.81	0.001348019	0.00238
57	28.5	1.95	1.81	0.001348019	0.00238
58	29	1.95	1.81	0.001348019	0.00238
59	29.5	1.95	1.81	0.001348019	0.00238
60	30	1.94	1.8	0.001340571	0.00238
61	30.5	1.94	1.8	0.001340571	0.00238
62	31	1.95	1.81	0.001348019	0.00238
63	31.5	1.95	1.81	0.001348019	0.00238
64	32	1.94	1.8	0.001340571	0.00238
65	32.5	1.93	1.79	0.001333124	0.00239
66	33	1.93	1.79	0.001333124	0.00239
67	33.5	1.94	1.8	0.001340571	0.00238
68	34	1.93	1.79	0.001333124	0.00239
69	34.5	1.92	1.78	0.001325676	0.00240
70	35	1.92	1.78	0.001325676	0.00240
71	35.5	1.93	1.79	0.001333124	0.00239
72	36	1.92	1.78	0.001325676	0.00240
73	36.5	1.93	1.79	0.001333124	0.00239
74	37	1.92	1.78	0.001325676	0.00240
75	37.5	1.92	1.78	0.001325676	0.00240
76	38	1.91	1.77	0.001318229	0.00241
77	38.5	1.92	1.78	0.001325676	0.00240
78	39	1.91	1.77	0.001318229	0.00241
79	39.5	1.92	1.78	0.001325676	0.00240
80	40	1.91	1.77	0.001318229	0.00241
81	40.5	1.91	1.77	0.001318229	0.00241
82	41	1.91	1.77	0.001318229	0.00241
83	41.5	1.91	1.77	0.001318229	0.00241
84	42	1.9	1.76	0.001310781	0.00241
85	42.5	1.91	1.77	0.001318229	0.00241
86	43	1.91	1.77	0.001318229	0.00241
87	43.5	1.9	1.76	0.001310781	0.00241
88	44	1.9	1.76	0.001310781	0.00241
89	44.5	1.9	1.76	0.001310781	0.00241
90	45	1.9	1.76	0.001310781	0.00241
91	45.5	1.9	1.76	0.001310781	0.00241
92	46	1.9	1.76	0.001310781	0.00241
93	46.5	1.9	1.76	0.001310781	0.00241

FYP II FINAL REPORT

Volume of solution (m^3) 0.0002
Temperature (°C) 30
Pressure (bar) 5 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2	n CO_2 / n amine
1	0.5	5.06	5	0.003969606	0.00000
2	1	4.76	4.7	0.003731429	0.00024
3	1.5	4.62	4.56	0.00362028	0.00035
4	2	4.52	4.46	0.003540888	0.00043
5	2.5	4.42	4.36	0.003461496	0.00051
6	3	4.34	4.28	0.003397982	0.00057
7	3.5	4.23	4.17	0.003310651	0.00066
8	4	4.15	4.09	0.003247137	0.00072
9	4.5	4.06	4	0.003175684	0.00079
10	5	3.99	3.93	0.00312011	0.00085
11	5.5	3.93	3.87	0.003072475	0.00090
12	6	3.85	3.79	0.003008961	0.00096
13	6.5	3.77	3.71	0.002945447	0.00102
14	7	3.72	3.66	0.002905751	0.00106
15	7.5	3.64	3.58	0.002842238	0.00113
16	8	3.58	3.52	0.002794602	0.00118
17	8.5	3.5	3.44	0.002731089	0.00124
18	9	3.44	3.38	0.002683453	0.00129
19	9.5	3.38	3.32	0.002635818	0.00133
20	10	3.32	3.26	0.002588183	0.00138
21	10.5	3.27	3.21	0.002548487	0.00142
22	11	3.22	3.16	0.002508791	0.00146
23	11.5	3.17	3.11	0.002469095	0.00150
24	12	3.11	3.05	0.002421459	0.00155
25	12.5	3.07	3.01	0.002389703	0.00158
26	13	3.02	2.96	0.002350006	0.00162
27	13.5	2.98	2.92	0.00231825	0.00165
28	14	2.93	2.87	0.002278554	0.00169
29	14.5	2.88	2.82	0.002238858	0.00173
30	15	2.84	2.78	0.002207101	0.00176
31	15.5	2.8	2.74	0.002175344	0.00179
32	16	2.75	2.69	0.002135648	0.00183
33	16.5	2.72	2.66	0.00211183	0.00186
34	17	2.68	2.62	0.002080073	0.00189
35	17.5	2.63	2.57	0.002040377	0.00193
36	18	2.57	2.51	0.001992742	0.00198
37	18.5	2.54	2.48	0.001968924	0.00200
38	19	2.5	2.44	0.001937167	0.00203
39	19.5	2.46	2.4	0.001905411	0.00206
40	20	2.41	2.35	0.001865715	0.00210
41	20.5	2.38	2.32	0.001841897	0.00213
42	21	2.35	2.29	0.001818079	0.00215
43	21.5	2.31	2.25	0.001786322	0.00218

FYP II FINAL REPORT

44	22	2.27	2.21	0.001754566	0.00222
45	22.5	2.25	2.19	0.001738687	0.00223
46	23	2.22	2.16	0.00171487	0.00225
47	23.5	2.19	2.13	0.001691052	0.00228
48	24	2.17	2.11	0.001675174	0.00229
49	24.5	2.13	2.07	0.001643417	0.00233
50	25	2.11	2.05	0.001627538	0.00234
51	25.5	2.08	2.02	0.001603721	0.00237
52	26	2.06	2	0.001587842	0.00238
53	26.5	2.02	1.96	0.001556085	0.00241
54	27	2	1.94	0.001540207	0.00243
55	27.5	1.97	1.91	0.001516389	0.00245
56	28	1.93	1.87	0.001484632	0.00248
57	28.5	1.91	1.85	0.001468754	0.00250
58	29	1.89	1.83	0.001452876	0.00252
59	29.5	1.86	1.8	0.001429058	0.00254
60	30	1.84	1.78	0.00141318	0.00256
61	30.5	1.82	1.76	0.001397301	0.00257
62	31	1.79	1.73	0.001373484	0.00260
63	31.5	1.77	1.71	0.001357605	0.00261
64	32	1.74	1.68	0.001333787	0.00264
65	32.5	1.73	1.67	0.001325848	0.00264
66	33	1.71	1.65	0.00130997	0.00266
67	33.5	1.7	1.64	0.001302031	0.00267
68	34	1.67	1.61	0.001278213	0.00269
69	34.5	1.65	1.59	0.001262335	0.00271
70	35	1.64	1.58	0.001254395	0.00272
71	35.5	1.62	1.56	0.001238517	0.00273
72	36	1.61	1.55	0.001230578	0.00274
73	36.5	1.6	1.54	0.001222639	0.00275
74	37	1.58	1.52	0.00120676	0.00276
75	37.5	1.57	1.51	0.001198821	0.00277
76	38	1.56	1.5	0.001190882	0.00278
77	38.5	1.54	1.48	0.001175003	0.00279
78	39	1.53	1.47	0.001167064	0.00280
79	39.5	1.52	1.46	0.001159125	0.00281
80	40	1.5	1.44	0.001143246	0.00283
81	40.5	1.5	1.44	0.001143246	0.00283
82	41	1.49	1.43	0.001135307	0.00283
83	41.5	1.47	1.41	0.001119429	0.00285
84	42	1.47	1.41	0.001119429	0.00285
85	42.5	1.46	1.4	0.00111149	0.00286
86	43	1.45	1.39	0.00110355	0.00287
87	43.5	1.44	1.38	0.001095611	0.00287
88	44	1.44	1.38	0.001095611	0.00287
89	44.5	1.43	1.37	0.001087672	0.00288
90	45	1.43	1.37	0.001087672	0.00288
91	45.5	1.42	1.36	0.001079733	0.00289

92	46	1.42	1.36	0.001079733	0.00289
93	46.5	1.41	1.35	0.001071793	0.00290
94	47	1.41	1.35	0.001071793	0.00290
95	47.5	1.41	1.35	0.001071793	0.00290
96	48	1.4	1.34	0.001063854	0.00291
97	48.5	1.4	1.34	0.001063854	0.00291
98	49	1.39	1.33	0.001055915	0.00291
99	49.5	1.4	1.34	0.001063854	0.00291
100	50	1.39	1.33	0.001055915	0.00291
101	50.5	1.38	1.32	0.001047976	0.00292
102	51	1.38	1.32	0.001047976	0.00292
103	51.5	1.37	1.31	0.001040037	0.00293
104	52	1.38	1.32	0.001047976	0.00292
105	52.5	1.39	1.33	0.001055915	0.00291
106	53	1.37	1.31	0.001040037	0.00293
107	53.5	1.38	1.32	0.001047976	0.00292
108	54	1.37	1.31	0.001040037	0.00293
109	54.5	1.37	1.31	0.001040037	0.00293
110	55	1.37	1.31	0.001040037	0.00293
111	55.5	1.36	1.3	0.001032097	0.00294
112	56	1.37	1.31	0.001040037	0.00293
113	56.5	1.36	1.3	0.001032097	0.00294
114	57	1.36	1.3	0.001032097	0.00294
115	57.5	1.37	1.31	0.001040037	0.00293
116	58	1.37	1.31	0.001040037	0.00293
117	58.5	1.37	1.31	0.001040037	0.00293
118	59	1.37	1.31	0.001040037	0.00293
119	59.5	1.37	1.31	0.001040037	0.00293
120	60	1.37	1.31	0.001040037	0.00293
121	60.5	1.37	1.31	0.001040037	0.00293
122	61	1.37	1.31	0.001040037	0.00293
123	61.5	1.37	1.31	0.001040037	0.00293
124	62	1.37	1.31	0.001040037	0.00293
125	62.5	1.37	1.31	0.001040037	0.00293
126	63	1.37	1.31	0.001040037	0.00293
127	63.5	1.37	1.31	0.001040037	0.00293
128	64	1.37	1.31	0.001040037	0.00293
129	64.5	1.37	1.31	0.001040037	0.00293
130	65	1.37	1.31	0.001040037	0.00293
131	65.5	1.37	1.31	0.001040037	0.00293
132	66	1.37	1.31	0.001040037	0.00293
133	66.5	1.36	1.3	0.001032097	0.00294
134	67	1.36	1.3	0.001032097	0.00294
135	67.5	1.36	1.3	0.001032097	0.00294
136	68	1.36	1.3	0.001032097	0.00294
137	68.5	1.36	1.3	0.001032097	0.00294
138	69	1.36	1.3	0.001032097	0.00294
139	69.5	1.36	1.3	0.001032097	0.00294

FYP II FINAL REPORT

140	70	1.36	1.3	0.001032097	0.00294
141	70.5	1.36	1.3	0.001032097	0.00294
142	71	1.36	1.3	0.001032097	0.00294
143	71.5	1.36	1.3	0.001032097	0.00294
144	72	1.36	1.3	0.001032097	0.00294
145	72.5	1.36	1.3	0.001032097	0.00294
146	73	1.36	1.3	0.001032097	0.00294
147	73.5	1.36	1.3	0.001032097	0.00294
148	74	1.36	1.3	0.001032097	0.00294
149	74.5	1.36	1.3	0.001032097	0.00294
150	75	1.36	1.3	0.001032097	0.00294
151	75.5	1.36	1.3	0.001032097	0.00294
152	76	1.36	1.3	0.001032097	0.00294
153	76.5	1.36	1.3	0.001032097	0.00294
154	77	1.36	1.3	0.001032097	0.00294
155	77.5	1.36	1.3	0.001032097	0.00294
156	78	1.36	1.3	0.001032097	0.00294
157	78.5	1.36	1.3	0.001032097	0.00294
158	79	1.36	1.3	0.001032097	0.00294
159	79.5	1.36	1.3	0.001032097	0.00294
160	80	1.36	1.3	0.001032097	0.00294
161	80.5	1.36	1.3	0.001032097	0.00294
162	81	1.36	1.3	0.001032097	0.00294
163	81.5	1.36	1.3	0.001032097	0.00294
164	82	1.36	1.3	0.001032097	0.00294
165	82.5	1.36	1.3	0.001032097	0.00294
166	83	1.36	1.3	0.001032097	0.00294
167	83.5	1.36	1.3	0.001032097	0.00294
168	84	1.36	1.3	0.001032097	0.00294
169	84.5	1.36	1.3	0.001032097	0.00294
170	85	1.36	1.3	0.001032097	0.00294
171	85.5	1.36	1.3	0.001032097	0.00294
172	86	1.36	1.3	0.001032097	0.00294
173	86.5	1.36	1.3	0.001032097	0.00294
174	87	1.36	1.3	0.001032097	0.00294
175	87.5	1.36	1.3	0.001032097	0.00294
176	88	1.36	1.3	0.001032097	0.00294
177	88.5	1.36	1.3	0.001032097	0.00294
178	89	1.36	1.3	0.001032097	0.00294
179	89.5	1.36	1.3	0.001032097	0.00294
180	90	1.36	1.3	0.001032097	0.00294

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	30
Volume of solution (m^3)	0.0002

94	47	1.9	1.76	0.001310781	0.00241
95	47.5	1.89	1.75	0.001303333	0.00242
96	48	1.9	1.76	0.001310781	0.00241
97	48.5	1.89	1.75	0.001303333	0.00242
98	49	1.89	1.75	0.001303333	0.00242
99	49.5	1.89	1.75	0.001303333	0.00242
100	50	1.89	1.75	0.001303333	0.00242
101	50.5	1.9	1.76	0.001310781	0.00241
102	51	1.89	1.75	0.001303333	0.00242
103	51.5	1.89	1.75	0.001303333	0.00242
104	52	1.89	1.75	0.001303333	0.00242
105	52.5	1.88	1.74	0.001295886	0.00243
106	53	1.89	1.75	0.001303333	0.00242
107	53.5	1.88	1.74	0.001295886	0.00243
108	54	1.89	1.75	0.001303333	0.00242
109	54.5	1.88	1.74	0.001295886	0.00243
110	55	1.88	1.74	0.001295886	0.00243
111	55.5	1.88	1.74	0.001295886	0.00243
112	56	1.89	1.75	0.001303333	0.00242
113	56.5	1.88	1.74	0.001295886	0.00243
114	57	1.88	1.74	0.001295886	0.00243
115	57.5	1.88	1.74	0.001295886	0.00243
116	58	1.88	1.74	0.001295886	0.00243
117	58.5	1.88	1.74	0.001295886	0.00243
118	59	1.88	1.74	0.001295886	0.00243
119	59.5	1.88	1.74	0.001295886	0.00243
120	60	1.88	1.74	0.001295886	0.00243
121	60.5	1.88	1.74	0.001295886	0.00243
122	61	1.88	1.74	0.001295886	0.00243
123	61.5	1.88	1.74	0.001295886	0.00243
124	62	1.88	1.74	0.001295886	0.00243
125	62.5	1.88	1.74	0.001295886	0.00243
126	63	1.88	1.74	0.001295886	0.00243
127	63.5	1.88	1.74	0.001295886	0.00243
128	64	1.88	1.74	0.001295886	0.00243
129	64.5	1.88	1.74	0.001295886	0.00243
130	65	1.88	1.74	0.001295886	0.00243
131	65.5	1.88	1.74	0.001295886	0.00243
132	66	1.88	1.74	0.001295886	0.00243
133	66.5	1.88	1.74	0.001295886	0.00243
134	67	1.88	1.74	0.001295886	0.00243
135	67.5	1.88	1.74	0.001295886	0.00243
136	68	1.88	1.74	0.001295886	0.00243
137	68.5	1.88	1.74	0.001295886	0.00243
138	69	1.88	1.74	0.001295886	0.00243
139	69.5	1.88	1.74	0.001295886	0.00243
140	70	1.88	1.74	0.001295886	0.00243
141	70.5	1.88	1.74	0.001295886	0.00243
142	71	1.88	1.74	0.001295886	0.00243

143	71.5	1.88	1.74	0.001295886	0.00243
144	72	1.88	1.74	0.001295886	0.00243
145	72.5	1.88	1.74	0.001295886	0.00243
146	73	1.88	1.74	0.001295886	0.00243
147	73.5	1.88	1.74	0.001295886	0.00243
148	74	1.88	1.74	0.001295886	0.00243
149	74.5	1.88	1.74	0.001295886	0.00243
150	75	1.88	1.74	0.001295886	0.00243
151	75.5	1.88	1.74	0.001295886	0.00243
152	76	1.88	1.74	0.001295886	0.00243
153	76.5	1.88	1.74	0.001295886	0.00243
154	77	1.88	1.74	0.001295886	0.00243
155	77.5	1.88	1.74	0.001295886	0.00243
156	78	1.88	1.74	0.001295886	0.00243
157	78.5	1.88	1.74	0.001295886	0.00243
158	79	1.88	1.74	0.001295886	0.00243
159	79.5	1.88	1.74	0.001295886	0.00243
160	80	1.88	1.74	0.001295886	0.00243
161	80.5	1.88	1.74	0.001295886	0.00243
162	81	1.88	1.74	0.001295886	0.00243
163	81.5	1.88	1.74	0.001295886	0.00243
164	82	1.88	1.74	0.001295886	0.00243
165	82.5	1.88	1.74	0.001295886	0.00243
166	83	1.88	1.74	0.001295886	0.00243
167	83.5	1.88	1.74	0.001295886	0.00243
168	84	1.88	1.74	0.001295886	0.00243
169	84.5	1.88	1.74	0.001295886	0.00243
170	85	1.88	1.74	0.001295886	0.00243
171	85.5	1.88	1.74	0.001295886	0.00243
172	86	1.88	1.74	0.001295886	0.00243
173	86.5	1.88	1.74	0.001295886	0.00243
174	87	1.88	1.74	0.001295886	0.00243
175	87.5	1.88	1.74	0.001295886	0.00243
176	88	1.88	1.74	0.001295886	0.00243
177	88.5	1.88	1.74	0.001295886	0.00243
178	89	1.88	1.74	0.001295886	0.00243
179	89.5	1.88	1.74	0.001295886	0.00243
180	90	1.88	1.74	0.001295886	0.00243

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002

94	47	1.54	1.38	0.001095611	0.00287
95	47.5	1.54	1.38	0.001095611	0.00287
96	48	1.54	1.38	0.001095611	0.00287
97	48.5	1.54	1.38	0.001095611	0.00287
98	49	1.54	1.38	0.001095611	0.00287
99	49.5	1.53	1.37	0.001087672	0.00288
100	50	1.53	1.37	0.001087672	0.00288
101	50.5	1.53	1.37	0.001087672	0.00288
102	51	1.53	1.37	0.001087672	0.00288
103	51.5	1.53	1.37	0.001087672	0.00288
104	52	1.52	1.36	0.001079733	0.00289
105	52.5	1.53	1.37	0.001087672	0.00288
106	53	1.52	1.36	0.001079733	0.00289
107	53.5	1.53	1.37	0.001087672	0.00288
108	54	1.53	1.37	0.001087672	0.00288
109	54.5	1.53	1.37	0.001087672	0.00288
110	55	1.53	1.37	0.001087672	0.00288
111	55.5	1.53	1.37	0.001087672	0.00288
112	56	1.52	1.36	0.001079733	0.00289
113	56.5	1.53	1.37	0.001087672	0.00288
114	57	1.52	1.36	0.001079733	0.00289
115	57.5	1.52	1.36	0.001079733	0.00289
116	58	1.52	1.36	0.001079733	0.00289
117	58.5	1.52	1.36	0.001079733	0.00289
118	59	1.51	1.35	0.001071793	0.00290
119	59.5	1.48	1.32	0.001047976	0.00292
120	60	1.46	1.3	0.001032097	0.00294
121	60.5	1.45	1.29	0.001024158	0.00295
122	61	1.44	1.28	0.001016219	0.00295
123	61.5	1.43	1.27	0.00100828	0.00296
124	62	1.42	1.26	0.001000341	0.00297
125	62.5	1.43	1.27	0.00100828	0.00296
126	63	1.4	1.24	0.000984462	0.00299
127	63.5	1.39	1.23	0.000976523	0.00299
128	64	1.38	1.22	0.000968584	0.00300
129	64.5	1.36	1.2	0.000952705	0.00302
130	65	1.35	1.19	0.000944766	0.00302
131	65.5	1.35	1.19	0.000944766	0.00302
132	66	1.35	1.19	0.000944766	0.00302
133	66.5	1.35	1.19	0.000944766	0.00302
134	67	1.35	1.19	0.000944766	0.00302
135	67.5	1.35	1.19	0.000944766	0.00302
136	68	1.35	1.19	0.000944766	0.00302
137	68.5	1.35	1.19	0.000944766	0.00302
138	69	1.35	1.19	0.000944766	0.00302
139	69.5	1.34	1.18	0.000936827	0.00303
140	70	1.34	1.18	0.000936827	0.00303
141	70.5	1.34	1.18	0.000936827	0.00303
142	71	1.34	1.18	0.000936827	0.00303

FYP II FINAL REPORT

143	71.5	1.34	1.18	0.000936827	0.00303
144	72	1.34	1.18	0.000936827	0.00303
145	72.5	1.34	1.18	0.000936827	0.00303
146	73	1.34	1.18	0.000936827	0.00303
147	73.5	1.34	1.18	0.000936827	0.00303
148	74	1.34	1.18	0.000936827	0.00303
149	74.5	1.34	1.18	0.000936827	0.00303
150	75	1.34	1.18	0.000936827	0.00303
151	75.5	1.34	1.18	0.000936827	0.00303
152	76	1.34	1.18	0.000936827	0.00303
153	76.5	1.34	1.18	0.000936827	0.00303
154	77	1.34	1.18	0.000936827	0.00303
155	77.5	1.34	1.18	0.000936827	0.00303
156	78	1.33	1.17	0.000928888	0.00304
157	78.5	1.33	1.17	0.000928888	0.00304
158	79	1.33	1.17	0.000928888	0.00304
159	79.5	1.33	1.17	0.000928888	0.00304
160	80	1.33	1.17	0.000928888	0.00304
161	80.5	1.33	1.17	0.000928888	0.00304
162	81	1.33	1.17	0.000928888	0.00304
163	81.5	1.33	1.17	0.000928888	0.00304
164	82	1.33	1.17	0.000928888	0.00304
165	82.5	1.33	1.17	0.000928888	0.00304
166	83	1.33	1.17	0.000928888	0.00304
167	83.5	1.33	1.17	0.000928888	0.00304
168	84	1.33	1.17	0.000928888	0.00304
169	84.5	1.33	1.17	0.000928888	0.00304
170	85	1.33	1.17	0.000928888	0.00304
171	85.5	1.33	1.17	0.000928888	0.00304
172	86	1.33	1.17	0.000928888	0.00304
173	86.5	1.33	1.17	0.000928888	0.00304
174	87	1.33	1.17	0.000928888	0.00304
175	87.5	1.33	1.17	0.000928888	0.00304
176	88	1.33	1.17	0.000928888	0.00304
177	88.5	1.34	1.18	0.000936827	0.00303
178	89	1.34	1.18	0.000936827	0.00303
179	89.5	1.34	1.18	0.000936827	0.00303
180	90	1.34	1.18	0.000936827	0.00303

Type of Amine	Methyl Diethanolamine/ Diethanolamine/ Piperazine
Total Solution Concentration (wt%)	50
Volume of solution (m^3)	0.0002

Temperature (°C) 50
Pressure (bar) 5 Bar

no	t(min)	P Total (bar)	P CO_2 (bar)	n CO_2	n CO_2 / n amine
1	0.5	5.03	5	0.00372381	0.00000
2	1	3.76	4.65	0.003463143	0.00026
3	1.5	3.41	3.98	0.002964152	0.00076
4	2	3.28	3.25	0.002420476	0.00130
5	2.5	3.27	3.24	0.002413029	0.00131
6	3	3.27	3.24	0.002413029	0.00131
7	3.5	3.27	3.24	0.002413029	0.00131
8	4	3.27	3.24	0.002413029	0.00131
9	4.5	2.98	2.95	0.002197048	0.00153
10	5	2.55	2.52	0.0018768	0.00185
11	5.5	2.3	2.27	0.00169061	0.00203
12	6	2.29	2.26	0.001683162	0.00204
13	6.5	1.8	1.77	0.001318229	0.00241
14	7	1.77	1.74	0.001295886	0.00243
15	7.5	1.7	1.67	0.001243752	0.00248
16	8	1.67	1.64	0.00122141	0.00250
17	8.5	1.65	1.62	0.001206514	0.00252
18	9	1.66	1.63	0.001213962	0.00251
19	9.5	1.65	1.62	0.001206514	0.00252
20	10	1.64	1.61	0.001199067	0.00252
21	10.5	1.63	1.6	0.001191619	0.00253
22	11	1.63	1.6	0.001191619	0.00253
23	11.5	1.63	1.6	0.001191619	0.00253
24	12	1.63	1.6	0.001191619	0.00253
25	12.5	1.63	1.6	0.001191619	0.00253
26	13	1.63	1.6	0.001191619	0.00253
27	13.5	1.63	1.6	0.001191619	0.00253
28	14	1.63	1.6	0.001191619	0.00253
29	14.5	1.63	1.6	0.001191619	0.00253
30	15	1.64	1.61	0.001199067	0.00252
31	15.5	1.64	1.61	0.001199067	0.00252
32	16	1.64	1.61	0.001199067	0.00252
33	16.5	1.62	1.59	0.001184171	0.00254
34	17	1.62	1.59	0.001184171	0.00254
35	17.5	1.62	1.59	0.001184171	0.00254
36	18	1.62	1.59	0.001184171	0.00254
37	18.5	1.62	1.59	0.001184171	0.00254
38	19	1.62	1.59	0.001184171	0.00254
39	19.5	1.62	1.59	0.001184171	0.00254
40	20	1.62	1.59	0.001184171	0.00254
41	20.5	1.62	1.59	0.001184171	0.00254
42	21	1.62	1.59	0.001184171	0.00254
43	21.5	1.62	1.59	0.001184171	0.00254
44	22	1.62	1.59	0.001184171	0.00254

FYP II FINAL REPORT

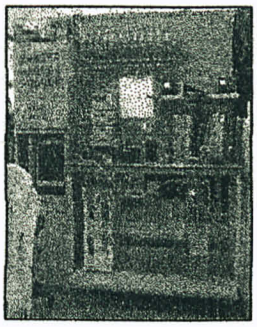
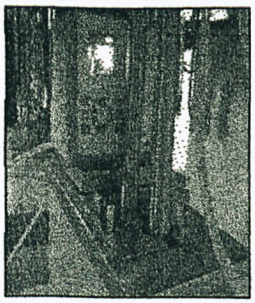
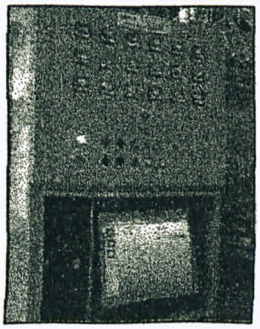
45	22.5	1.62	1.59	0.001184171	0.00254
46	23	1.62	1.59	0.001184171	0.00254
47	23.5	1.62	1.59	0.001184171	0.00254
48	24	1.62	1.59	0.001184171	0.00254
49	24.5	1.62	1.59	0.001184171	0.00254
50	25	1.62	1.59	0.001184171	0.00254
51	25.5	1.62	1.59	0.001184171	0.00254
52	26	1.62	1.59	0.001184171	0.00254
53	26.5	1.62	1.59	0.001184171	0.00254
54	27	1.62	1.59	0.001184171	0.00254
55	27.5	1.62	1.59	0.001184171	0.00254
56	28	1.62	1.59	0.001184171	0.00254
57	28.5	1.62	1.59	0.001184171	0.00254
58	29	1.62	1.59	0.001184171	0.00254
59	29.5	1.62	1.59	0.001184171	0.00254
60	30	1.62	1.59	0.001184171	0.00254
61	30.5	1.62	1.59	0.001184171	0.00254
62	31	1.62	1.59	0.001184171	0.00254
63	31.5	1.62	1.59	0.001184171	0.00254
64	32	1.62	1.59	0.001184171	0.00254
65	32.5	1.62	1.59	0.001184171	0.00254
66	33	1.62	1.59	0.001184171	0.00254
67	33.5	1.62	1.59	0.001184171	0.00254
68	34	1.62	1.59	0.001184171	0.00254
69	34.5	1.62	1.59	0.001184171	0.00254
70	35	1.62	1.59	0.001184171	0.00254
71	35.5	1.62	1.59	0.001184171	0.00254
72	36	1.62	1.59	0.001184171	0.00254
73	36.5	1.62	1.59	0.001184171	0.00254
74	37	1.62	1.59	0.001184171	0.00254
75	37.5	1.62	1.59	0.001184171	0.00254
76	38	1.62	1.59	0.001184171	0.00254
77	38.5	1.62	1.59	0.001184171	0.00254
78	39	1.62	1.59	0.001184171	0.00254
79	39.5	1.62	1.59	0.001184171	0.00254
80	40	1.62	1.59	0.001184171	0.00254
81	40.5	1.62	1.59	0.001184171	0.00254
82	41	1.62	1.59	0.001184171	0.00254
83	41.5	1.62	1.59	0.001184171	0.00254
84	42	1.62	1.59	0.001184171	0.00254
85	42.5	1.62	1.59	0.001184171	0.00254
86	43	1.62	1.59	0.001184171	0.00254
87	43.5	1.62	1.59	0.001184171	0.00254
88	44	1.62	1.59	0.001184171	0.00254
89	44.5	1.62	1.59	0.001184171	0.00254
90	45	1.62	1.59	0.001184171	0.00254
91	45.5	1.62	1.59	0.001184171	0.00254
92	46	1.62	1.59	0.001184171	0.00254
93	46.5	1.62	1.59	0.001184171	0.00254

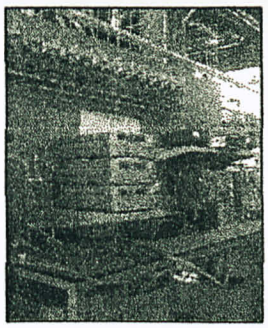
94	47	1.62	1.59	0.001184171	0.00254
95	47.5	1.62	1.59	0.001184171	0.00254
96	48	1.62	1.59	0.001184171	0.00254
97	48.5	1.62	1.59	0.001184171	0.00254
98	49	1.62	1.59	0.001184171	0.00254
99	49.5	1.62	1.59	0.001184171	0.00254
100	50	1.62	1.59	0.001184171	0.00254
101	50.5	1.62	1.59	0.001184171	0.00254
102	51	1.62	1.59	0.001184171	0.00254
103	51.5	1.62	1.59	0.001184171	0.00254
104	52	1.62	1.59	0.001184171	0.00254
105	52.5	1.62	1.59	0.001184171	0.00254
106	53	1.62	1.59	0.001184171	0.00254
107	53.5	1.62	1.59	0.001184171	0.00254
108	54	1.62	1.59	0.001184171	0.00254
109	54.5	1.62	1.59	0.001184171	0.00254
110	55	1.62	1.59	0.001184171	0.00254
111	55.5	1.62	1.59	0.001184171	0.00254
112	56	1.62	1.59	0.001184171	0.00254
113	56.5	1.62	1.59	0.001184171	0.00254
114	57	1.62	1.59	0.001184171	0.00254
115	57.5	1.62	1.59	0.001184171	0.00254
116	58	1.62	1.59	0.001184171	0.00254
117	58.5	1.62	1.59	0.001184171	0.00254
118	59	1.62	1.59	0.001184171	0.00254
119	59.5	1.62	1.59	0.001184171	0.00254
120	60	1.62	1.59	0.001184171	0.00254
121	60.5	1.62	1.59	0.001184171	0.00254
122	61	1.62	1.59	0.001184171	0.00254
123	61.5	1.62	1.59	0.001184171	0.00254
124	62	1.62	1.59	0.001184171	0.00254
125	62.5	1.62	1.59	0.001184171	0.00254
126	63	1.62	1.59	0.001184171	0.00254
127	63.5	1.62	1.59	0.001184171	0.00254
128	64	1.62	1.59	0.001184171	0.00254
129	64.5	1.62	1.59	0.001184171	0.00254
130	65	1.62	1.59	0.001184171	0.00254
131	65.5	1.62	1.59	0.001184171	0.00254
132	66	1.62	1.59	0.001184171	0.00254
133	66.5	1.62	1.59	0.001184171	0.00254
134	67	1.62	1.59	0.001184171	0.00254
135	67.5	1.62	1.59	0.001184171	0.00254
136	68	1.62	1.59	0.001184171	0.00254
137	68.5	1.62	1.59	0.001184171	0.00254
138	69	1.62	1.59	0.001184171	0.00254
139	69.5	1.62	1.59	0.001184171	0.00254
140	70	1.62	1.59	0.001184171	0.00254
141	70.5	1.62	1.59	0.001184171	0.00254
142	71	1.62	1.59	0.001184171	0.00254

143	71.5	1.62	1.59	0.001184171	0.00254
144	72	1.62	1.59	0.001262335	0.00246
145	72.5	1.62	1.59	0.001262335	0.00246
146	73	1.62	1.59	0.001262335	0.00246
147	73.5	1.62	1.59	0.001262335	0.00246
148	74	1.62	1.59	0.001262335	0.00246
149	74.5	1.62	1.59	0.001262335	0.00246
150	75	1.62	1.59	0.001262335	0.00246
151	75.5	1.62	1.59	0.001262335	0.00246
152	76	1.62	1.59	0.001262335	0.00246
153	76.5	1.62	1.59	0.001262335	0.00246
154	77	1.62	1.59	0.001262335	0.00246
155	77.5	1.62	1.59	0.001262335	0.00246
156	78	1.62	1.59	0.001262335	0.00246
157	78.5	1.62	1.59	0.001262335	0.00246
158	79	1.62	1.59	0.001262335	0.00246
159	79.5	1.62	1.59	0.001262335	0.00246
160	80	1.62	1.59	0.001262335	0.00246
161	80.5	1.62	1.59	0.001262335	0.00246
162	81	1.62	1.59	0.001262335	0.00246
163	81.5	1.62	1.59	0.001262335	0.00246
164	82	1.62	1.59	0.001262335	0.00246
165	82.5	1.62	1.59	0.001262335	0.00246
166	83	1.62	1.59	0.001262335	0.00246
167	83.5	1.62	1.59	0.001262335	0.00246
168	84	1.62	1.59	0.001262335	0.00246
169	84.5	1.62	1.59	0.001262335	0.00246
170	85	1.62	1.59	0.001262335	0.00246
171	85.5	1.62	1.59	0.001262335	0.00246
172	86	1.62	1.59	0.001262335	0.00246
173	86.5	1.62	1.59	0.001262335	0.00246
174	87	1.62	1.59	0.001262335	0.00246
175	87.5	1.62	1.59	0.001262335	0.00246
176	88	1.62	1.59	0.001262335	0.00246
177	88.5	1.62	1.59	0.001262335	0.00246
178	89	1.62	1.59	0.001262335	0.00246
179	89.5	1.62	1.59	0.001262335	0.00246
180	90	1.62	1.59	0.001262335	0.00246

Appendix D

✓ Laboratory Experiment Images

Image	Remarks
	• Complete image of BP Model 22
	• Checking/ Setting up desired pressure of N_2 cylinder and CO_2 cylinder before starting the experiment
	• Setting up the temperature bath up to the desired temperature of 30°C and 50°C
	• Display Process Flow Diagram of System • System partial pressure, temperature and other parameters are monitored during the experiment

	• Purging the solubility cell with N_2 before introducing CO_2 gas into the system
	• Vacuum pump (far left) is used to create vacuum in the system after purging is complete. • Gas booster (far right) is used to compress CO_2 gas into the mixing cell.
	• Multiple pipelines for mixing of various gases. In this case, only two pipelines are used which is CO_2 and N_2 pipelines.